JOURNAL

OF

THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

DECEMBER, 1861.

CIVIL ENGINEERING.

Suspension Girder Bridges for Railway Traffic.

From the Lond. Civ. Eng. and Arch. Journal, Dec., 1860.

(Continued from page 298.)

LET us now pass on to the consideration of the condition which imposes the severest possible strain upon the suspended girder, namely, the distribution of a load over half the girder next one tower. Here we have no experiments recorded that supply any check to theoretical calculation. We may however the less regret the omission, when we find that the condition just supposed is the one in which the problem assumes its very simplest form.

We have already presented the result of the investigation of the effect of the concentrated weight w placed on the suspended girder, at a point whose distance d from the centre bears to the entire span s the ratio $\frac{d}{s}=r$. We found that the load thrown on the chains would be

$$\left(\frac{25}{16}-\frac{15}{2}r^2+5r^4\right)\times w;$$

and thence deduced the ordinate of the reflex wave. If for a concentrated load at one point we substitute a load equably distributed between two points (at the respective distances $d=rs$, and $d_2=r_2 s$,

from the centre), the rate of loading per foot forward being denoted by m, the load thrown on the chains will be readily found by integration to be equal to the following expression:—

$$\text{Load on chains} = \left(\frac{25}{16}(r_2 - r) - \frac{5}{2}(r_2^3 - r^3) + r_2^5 - r^5\right) \times ms.$$

And when one half-span is equably loaded, and the other half-span not loaded—that is to say, when $r_2 = \frac{1}{2}$ and $r = 0$, we find that

$$\text{Load on chains} = \left(\frac{25}{16} \times \frac{1}{2} - \frac{5}{2} \times \frac{1}{8} + \frac{1}{32}\right) \times ms = \frac{ms}{2},$$

which is exactly the amount of the load distributed over the half-span of the girder.

A load therefore, say of 100 tons, distributed over half the span of the suspended girder, induces an upward reaction in the chains equal to 100 tons distributed over the whole span. The unloaded half of the girder will therefore have to sustain an upward distributed pressure (from the chains) equal to 50 tons; the loaded half of the girder will have to sustain the difference between its load of 100 tons and the upward reaction of the chains, which will be 50 tons: this difference amounts to 50 tons, and is the net downward distributed pressure on the loaded portion of the girder.

It is therefore obvious that, apart from the stretching of the chains, the suspended girder will in this case assume a perfectly symmetrical S curve; the upward flexure of the unloaded half of the girder being exactly similar and equal to the downward flexure of the loaded half. The same result is arrived at by combining the simple wave of deflection with the reflex wave.

It thus appears that *for a bridge of a single span only*, the greatest strain which a given rolling load can throw on the suspended girder is $\frac{1}{8}$th of the greatest strain which it would throw on an ordinary girder not suspended.

Take, for instance, a bridge of 400 feet span, with a rolling load of 1 ton per foot forward. For a common girder bridge the greatest strain will be that which is sustained at the centre when the whole bridge is loaded; and will be represented by the product of 400 (the load in tons), and 50 (the eighth part of the span). This product is 20,000. For a suspended girder the greatest strain will be that which arises at the quarter-span, when the half-span is loaded. The rolling load is in this case 200 tons; but as the upward reaction of the chains distributed over the half-span is 100 tons, the load sustained by the girder is only 100 tons. The strain will therefore be represented by the product of 100 (the virtual load in tons), and 25 (the eighth part of the half-span). This product is 2500, which is $\frac{1}{8}$th of 20,000, the greatest strain on the simple girder bridge.

We have hitherto postponed the consideration of the stretching of the chains when the rolling load comes on the bridge, and the consequent depression of the reflex wave. Let us suppose a uniform elonga-

tion of the chain, at the rate $1 : 1 + e$; and s being the span, let v be the rise of the curve of the chains; then $\frac{25e}{32}\left(\frac{s^2}{4v}, + \frac{4v}{3}\right)$ is the expression for the settlement at the half-span due to the assumed amount of stretching of chain; and this will be the consequent diminution of the sagitta of the reflex wave.

The rise or fall of the girder occasioned by the contraction or expansion of the chains on change of temperature is expressed in a form identical with the preceding; and the consequent strain on either flanch of the girder can be readily computed when the depth of the girder is known. And when the section of the girder is known, it will be easily ascertained what amount of additional load is thrown upon it, from the deflection attending the stretching or the expansion of the chains.

In brief, for a bridge of a single span, the section of the suspended girder should be calculated to give $\frac{1}{8}$th, not of the entire strength of a simple bridge girder for the same span, but of so much only of its strength as is assigned to the support of the maximum rolling load. This distinction is one of great moment where heavy spans are encountered, and indicates the extreme economy of the suspended girder in such cases. All the fixed dead weight, inclusive of the weight of the girders themselves, is carried by the chains; with the exception that, when these expand or are stretched, a small distributed load is thrown on the girders. A *small* distributed load, because a girder of the proportionate strength required, and of a depth from one-third to one-half of the rise of the chains, will readily rise and fall to the necessary extent, without sustaining much strain. The girders could, moreover, be strained up to a camber, in fixing, so as greatly to reduce the downward strain resulting from the elongation of the chains.

As an illustration of this, let us suppose that the chains of a bridge of 400 feet span have a rise of 50 feet, and carry a girder of such rigidity that a distributed load of 50 tons would cause it to deflect 10 inches, were the support of the chains withheld. If a rolling load of 400 tons, covering the whole bridge, causes the chains to stretch $\frac{1}{200}$th part of their length, the resulting deflection will be 4 inches: but the girder in deflecting 4 inches has a distributed load of only $\frac{4}{10}$ths $\times 50$, or 20 tons, thrown upon it, leaving 380 tons as the share of the rolling load sustained by the chains. And were the girder strained up in fixing to a 4-inch camber (representing an upward pressure of 20 tons), the effect of the stretching of the chains would be simply to release the girder from its forced camber, so as to leave it free from strain when the bridge is covered with its maximum rolling load.

Apart from the deflection or settlement alluded to, the maximum rolling road will cause an extreme deflection at the quarter-span, equal to $\frac{1}{3\frac{1}{2}}$ of the deflection which would take place at the centre of the same girder, under the same rolling load, without the chains; or about $\frac{1}{4}$th of the extreme deflection of an ordinary girder bridge of the same span and same depth of girder.

The case of the suspended girder, for a single span, having been thus far investigated, we may proceed to examine how the conditions become modified when there are more spans than one. If we suppose that, of two adjacent spans, one is loaded and the other not, we find that the chains on the opposite sides of the intervening pier will in the first instance be in very unequal states of tension, and that the one chain must sink and the other rise, until the equilibrium of tension is restored. This is presuming that the chains are connected, as is usual, by means of a saddle placed on rollers, so as to admit of such adjustment, and relieve the pier of any horizontal strain.

The necessity of this or some equivalent precaution, becomes manifest when we consider the nature of the horizontal strain that would otherwise be thrown on the pier or tower intervening between an unloaded and a loaded span. Take for instance two adjacent spans, each of 400 feet, of which one has only its fixed dead load, while the other is covered by a rolling load of 400 tons. If the rise of the chains be 50 feet, the horizontal tension of the one pair of chains will exceed that of the adjacent pair by 400 tons; so that, if the summits of the chains were made fast to the top of the tower (instead of being allowed to slide upon it), the tower would have to sustain a horizontal pull of 400 tons, tending to draw it over into the loaded bay. Could an ordinary pier be trusted to sustain a strain of this nature and magnitude, the foregoing part of our inquiry would be as applicable to bridges consisting of two or more, as to those of a single span; but prudence is generally considered to demand the exemption of masonry piers from such a formidable horizontal strain. Where iron is substituted for masonry, and a very extended base given, the towers might possibly be made to sustain a strain of this nature. But in such a case the summits of the towers would cease to be absolutely dead points, since unequal compression in the iron would inevitably cause a slight horizontal deflection towards the more heavily loaded span. This deflection, or swaying, of the tower, if only a few inches, would cause such a deflection in the loaded girder as we wish to avoid. We may therefore pursue our investigation into the case of two adjacent spans unequally loaded, the chains being allowed free play on the top of the intervening pier.

The function of the suspended girders will now be to equalize the strain on the chains, so as to insure equilibrium, before the deflection of one span and the drawing up of the other (which without the girders might be objectionably great) exceed some small fixed limit. If therefore, one span being unloaded, the adjacent span is covered with a rolling load of 100 tons, the action of the girders must be such as to throw a distributed load of 50 tons on each set of chains. The girders of the loaded span will therefore have to sustain a sensible load of 50 tons, the remaining 50 tons of rolling load being borne by the chains. At the same time, in the unloaded span, the reaction of the chains will distribute an upward pressure of 50 tons over the girders. These results will of course be modified by the stretching of the chains, which will diminish the rise in the one span, and increase the deflection in

the other. It is perhaps hardly necessary to remark, that as the waves in the adjacent spans are of opposite kinds, they will in no way be affected by continuity in the girders.

For a suspension bridge of more spans than one, designed for railway traffic, it therefore appears essential to provide girders capable of sustaining a distributed load equal to half the maximum rolling load. These girders should not be of a depth exceeding from one-third to one-half the rise of the chains. For large spans—and it is for large spans only that a suspension bridge would be constructed to carry railway traffic—these girders, having to support neither their own weight, nor any other portion of the dead load, but simply half the maximum rolling load, will be light in comparison with the girders for an ordinary bridge of equal span. They will be sufficiently flexible to follow the rise and fall of the chains; never ceasing to be truly *suspended* girders, at the same time that they possess rigidity enough to distribute any partial load equably over the chains, and to keep the wave caused by the rolling load within moderate and safe limits.

After what has been said, it is obvious that the economy of the suspended girder is greater for a single span than for a bridge of more spans than one, since the girder in the latter must be four times as strong as that in the former. The deflection in the bridge of one span only will (as we have seen) be one-fourth of the deflection of an ordinary girder bridge of the same span and same depth of girder; while in the multiple span bridge the deflection becomes equal to that of the ordinary girder bridge. The deflection in each case has, however, to be increased by the amount of settlement due to the stretching of the chains when the maximum rolling load traverses the bridge.

On examining the expression for this settlement, which has been already given as $\frac{25e}{32}\left(\frac{s^2}{4v}+\frac{4v}{3}\right)$, we find that it diminishes as the rise of the chains increases; reaching a minimum when the rise of the chains equals the altitude of an equilateral triangle having for its base half the span of the bridge. By giving a considerable rise to the chains, we therefore effect a saving of strength, and thus of material, not simply in the chains themselves, but also in the suspended girder, by reducing the strain on the latter resulting from settlement.

It may be as well before dismissing the subject, to add a word or two on the resistance offered by the chains *per se* to an irregular displacement, and the amount of error involved at the outset of this inquiry in neglecting this element of stability; and considering the *form* of the reflex wave as entirely governed by the law of the girder, while its *magnitude* depends on the law of continuity of the chains. If we take the same example as before, viz: a bridge 400 feet span, 50 feet rise of chain, and a dead load of 300 tons, inclusive of weight of chains and girder; and suppose a weight of 1 ton placed at the quarter-span; the chains over the same point would be drawn down about 1 inch, if there were no girder. But if we take the girder (of the same strength as calculated before for the single span), we

shall find that it will take a weight of more than 5½ tons at the quarter-span to cause an inch deflection, without the chains. In this case, therefore, the resistance of the chains to a small displacement would be about 18 per cent. of that of the girder, and would tend to reduce the wave calculated on the preceding principles by a like per centage. But there is also another consideration to be taken into account, operating the other way. When the rolling load comes on a bridge the added strain will cause the stay-chains to stretch, and this will occasion an increase in the deflection of the bridge. There are thus two causes, one of diminished, the other of increased disturbance, which to some extent counteract one another, and which are not reducible to a general rule, as they vary with the conditions of each bridge. Their operation therefore has to be specially calculated, and allowance made for them, when applying the results of general theory to any particular case.

It must be borne in mind that the displacements we have been investigating are *very small*, consisting of inches, where the span consists of hundreds of feet. The resistance of the chain rapidly increases when the displacements become large enough to cause an appreciable alteration in the rate of curvature of the chain. In this respect the chain has a very different law from the girder. If a load of 50 tons deflect a girder 10 inches, we may expect a deflection of 1 inch for a load of 5 tons. Not so with the partial displacements of a chain. If 50 tons caused a displacement of 20 inches, it would by no means be a just inference that 5 tons would cause a displacement of only 2 inches. Thus, in a model in which the wave is greatly magnified, and especially when there is a large distributed dead load on the platform, the action of the chains in reducing the wave will be proportionately much greater than in the actual bridge. As we have already seen, the wave in Mr. Barlow's model is in each instance less than theory would indicate; and the more so as the stiffness of the girder is reduced, or the distributed dead load increased. The consideration just adduced furnishes a clue to this discrepancy.

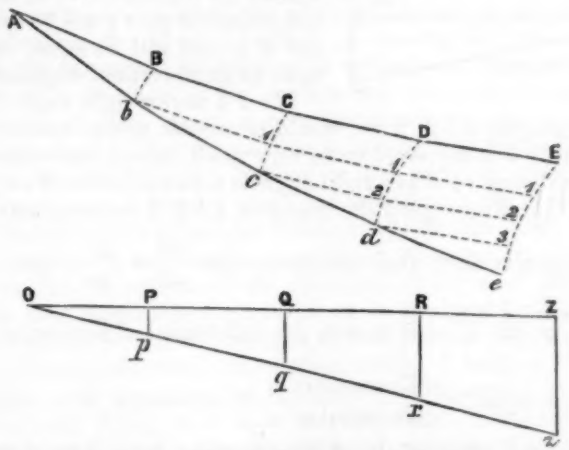
While therefore the strength of the chain is sufficient to carry a load that would prove destructive to the girder, if not suspended, the resistance of the girder to small partial displacements is far more powerful than that of the chain. For the strength of the girder consists in its rigidity; whereas the equilibrium of the chain is dependent on its readily adapting itself to any particular curve required by the distribution of the rolling load at a given moment. The suspended girder, by virtue of its rigidity, transmits a partial load to the chain in the form of an equally distributed pressure. Thus the girder preserves the equilibrium of the curve of the chain, while the chain furnishes the ultimate support of the whole, or nearly the whole, of the load.

It is perhaps due to the reader to explain how we arrive at the general expression for the horizontal displacement resulting from the deflection, or the pulling up, of a chain; the more so, as it forms, in

fact, the basis of the whole of the foregoing investigation. The general expression referred to is $\int \frac{dy}{dx} . dz$, given *ante* p. 318 (293 *Journal*).

In fig. 1, A B C D E represents part of a chain in its original position, and A *b c d e* is the same chain after displacement; the point A is supposed to be fixed. O Z being a horizontal line, O *p q r z* is the curve of the vertical displacements of the chain, the ordinate P *p* being equal to the difference in height between B and *b*; the ordinate Q *q* to the difference in height between C and *c*, and so on. The displacements are supposed to be small, although in the diagram it is necessary to make them large, for the sake of clearness. The length of chain A *b* is equal to A B, *b c* to B C, and so on to *e*. Each length of the chain except A B undergoes at once a change of *place* and a change of *direction*. The change of place is again resolvable into *vertical* displacement, which is already plotted in the ordinates of the curve O *z*; and *horizontal* displacement, which is what we want to determine, and

Fig. 1.



which is the aggregate effect of the changes of position of the successive lengths of chain. It will assist the understanding if we distinguish between the change of place and the change of direction, by considering them as sucessive instead of simultaneous.

First, then, A B assumes the position A *b*. The necessary result is a change of position of the remainder of the chain B C D E to *b* 1 1 1; the points C, D, and E taking a parallel motion equal to B *b*, as indicated by the dotted lines C 1, &c., so as to produce change of place without change of direction.

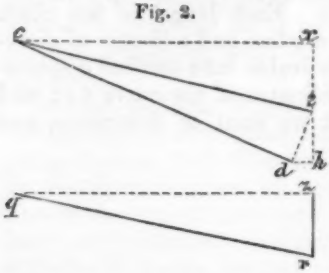
Next, let B C, after moving as we have seen to the position *b* 1, undergo its change of *direction*, assuming that of *b c*. C D E will now sustain a second change of place, viz: from 1 1 1 to *c* 2 2, the dotted lines 1 2 (indicating the path of this movement) being equal and parallel to 1 *c*.

The next step is for $c\,2$ to fall into its new direction, $c\,d$: this will be attended by a parallel movement of $2\,2$ to $d\,3$. Lastly, $d\,3$ assumes its ultimate direction, $d\,e$.

By thus laying down the paths, E 1 2 3 *e*, D 1 2 *d*, &c., in which the various points in the chain may be supposed to travel to their new positions, it is rendered obvious that the displacement of E, both vertical and horizontal, is the sum of the effects of the changes of *direction* of the several lengths of chain. So that if we find the horizontal movements given by the change of direction of A B, B C, &c., and add them, the sum will be the amount of horizontal displacement at *e*.

Fig. 2 gives an enlarged view of a length $c\,2$ of the chain, and its movement to its ultimate direction, $c\,d$; $q\,r$ is a corresponding portion of the curve of deflection. x and y being the horizontal and vertical ordinates of the point c, as measured from some fixed centre or origin, $c\,x$ in the diagram will be the differential of x, and $x\,2$ the differential of y: $r\,z$ will be the differential of z, and will be equal to the element $(h\,2)$ of vertical displacement.

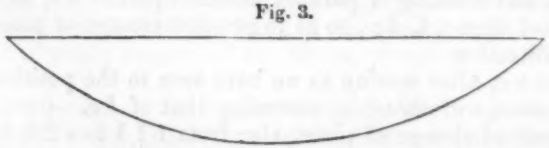
Fig. 2.



If $c\,2\,d$ were a right angle, the right-angled triangles $d\,h\,2$, $2\,x\,c$, would be similar to one another; but as the angle $2\,c\,d$ is supposed to be very small indeed, the error resulting from considering $c\,2\,d$ as a right angle is too small to be of any account. We may therefore regard the triangles $d\,h\,2$, $2\,x\,c$, as absolutely similar. It results from their similarity that $\frac{dh}{h2} = \frac{2x}{xc}$; and therefore $d\,h = \frac{2x}{x\,c} \times h2$. That is to say, the differential of horizontal displacement (dh) is equal to $\frac{\text{differential of } y}{\text{differential of } x} \times$ differential of z. The sum of the horizontal differentials of displacement from A to E (fig. 1) will therefore be equal to $\int \frac{dy}{dx} . dz$, between the same points; so that this expression gives—with a minute error—the actual horizontal displacement of *e*.

We add by way of illustration three figures, to a magnified vertical

Fig. 3.



scale. Fig. 3 is the wave of simple deflection which the girder would fall into without the support of the chains, when half the rolling load

was on the bridge. In fig. 4, the dotted curve shows the reflex wave in which the chain (to preserve its continuity) would draw up the girder, were it not for the stretching: the full line shows the *actual* reflex

Fig. 4.

wave, allowing for the stretching. Fig. 5 exhibits the compound wave which results from the simultaneous action of the wave of deflection in fig. 3 and the reflex wave in fig. 4. The dotted line shows the

Fig. 5.

equal rise and depression which would take place if the chains did not stretch: the full line shows the actual result after the settlement of the chains.

We have now accomplished the object proposed in this article, by briefly indicating the steps by which an intelligible and consistent theory of the suspended girder may be arrived at; comparing its results with those obtained by Mr. Barlow from his experimental model; and pointing out those practical conclusions which seem most obvious or most important. We refrain from inquiring into the sufficiency of the girder proposed by Mr. Barlow for the multiple span bridge at Londonderry, as such inquiry would not come within our present scope. The application of the principles attempted to be laid down to the examination of this or any similar case would, however, be very readily made, provided the section of the intended girder were given. The conclusion that immediately concerns us is the practicability of the suspended girder for railway bridges of heavy spans; the marked economy, moderate deflection, and perfect safety of bridges constructed on this plan; and the proportions and other conditions to be observed. Experiment and theory have now done their part. Each involve some known, and possibly also some unsuspected, sources of error. It remains for the practical engineer, by the bold test of some actual work, at once to correct and verify the conclusions of abstract science, and remove the question for ever from the province of discussion.

PROCEEDINGS OF THE BRITISH ASSOCIATION.

From the Lond. Athenæum, Sept., 1861.

Section G.—*Mechanical Science.*

Dr. Eddy read "A Proposal for a Class of Gunboats capable of engaging Armor-plated Ships at Sea, accompanied with Suggestions for fastening on Armor-plates." He considered that the monster iron-clad vessels which we and our neighbors were building, might be successfully assailed by vessels of very inferior size specially

designed for the purpose. The first essential condition of such vessels was superiority of speed, and so protected as to approach them without being crippled: and he believed that one such vessel with a couple of heavy guns might so harass a larger vessel as to paralyze her movements, and that two such vessels might even engage with advantage; and, if this was so, might not a flotilla of these small vessels advantageously engage a fleet of the large iron-plated ships? To obtain superior speed, we must either sacrifice weight of metal or increase the size. He preferred the former, and by reducing the armament to a very few guns—two or four—and those of the powerful kind now manufactured, he thought we might obtain the required speed within moderate dimensions; and he hoped to show that, by a peculiar adjustment of material, we might gain all the protection required, without immoderate weight. Much of this problem had indeed been worked out by Captain Coles, of whose cupola, the conical fort, with revolving shield, in the model produced, was a modification. A speed of sixteen knots an hour would, he believed, be sufficient for present purposes, and he took it that this speed might be secured without difficulty in a vessel of fine lines, and of certain proportions, without tremendous size. Dr. Eddy proceeded to describe from a model the kind of gunboat he proposed to build. The dimensions, he said, were calculated from one datum, namely, the least elevation above water at which the guns could advantageously be laid, which he took to be 8 feet. In this position, then, he would place two of the heaviest Armstrong guns, with their muzzles 4½ feet apart, on an inclined slide, upon a turn-table placed within a fixed conical fort, armor clad, the sides of which sloped at an angle of 45°. Above this, for a perpendicular height of 4 feet, he would protect the guns and gunners with a shield of iron plate, also at an angle of 45°. The shape of the fort would be a truncated cone on a cylinder, like an extinguisher upon a candlestick. A second cupola he believed, might be added, and this would give an armament of four guns, which, if concentrated upon one point at short range, must have a crushing effect. But, to be of any use, the smaller vessel must be enabled to approach her large antagonist without risk of having a shot sent through her bottom from the enemy's depressed guns. The manner in which he proposed to fortify the gunboat, was by keeping all the vital parts well below the water-line, and covering them with a deck which would deflect upwards any shot that might reach it. As the boat was only intended to attack ships, not forts, he presumed there was no need to apprehend a shot striking her at a larger angle with the horizon than 7°. Still at this angle, to protect the sides of the vessel effectually, the armor must be carried at least 4 feet above water, and 3 feet below, possibly more; but as this involved a weight of 300 tons in plating alone, some other method of protection must be sought. He hoped he had found this desideratum in a plan which aimed at carrying out thoroughly the principle of deflection. His plan consisted of an arched deck of inch iron resting upon two courses of timber, the extremities of the arch being tied, so as to neutralize the outward thrust. He pro-

posed that this should spring at the sides from three feet below the water-line, and that the crown should rise amidships up to the water-line, the crown being kept tolerably flat, the object being to present so small an angle that even a flat-headed bolt should glance off. The space above the deck and between it and the water-line he proposed to pack with some tough and resilient but light fibre, and these qualities he found combined in the cocoa-nut fibre, which could be easily rendered incombustible by sal-ammoniac. This fibre would offer a considerable amount of resistance to the penetration of a shot, and in proportion to the resistance would tend to deflect the shot. The exact amount of resistance which this mode of packing would afford could not be ascertained without experiment, but the trial would not be expensive. He might be met with the objection, that steel or iron was the substance which offered the greatest amount of protection proportionate to its weight. Granting this, he maintained that there were circumstances under which iron alone could not be advantageously used, and that this was one. Dr. Eddy alluded to the difficulty now felt in securing the iron plates on the sides of the vessels without weakening them by perforating holes, and he mentioned a plan of screwing the plates within a rail-shaped frame, which he said he had been encouraged by Mr. Fairbairn to lay before the Section, and which he thought would obviate the difficulty.

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Capt. Blakely, R. A., then brought forward his paper "On ARTILLERY *versus* ARMOR."—He said it was now four years since he first developed at Dublin his ideas with reference to the strength and extent of range which might be obtained with a particular description of cannon. He was happy to think that the principle he then contended for had since been recognised by both the English and Spanish governments to be correct. With great deference to the opinion of Sir William Armstrong, he must state, as the result of his experiments, that nearly every kind of steel he had used was better than every kind of wrought iron. Cast iron, where weight was no objection, he found to answer admirably. Capt. Blakely exhibited the drawing of the new Spanish gun, and explained its construction. The diameter of the bore was between six and seven inches; more than half of the gun, he said, was of cast iron, the upper portion of the breech only being formed of rings of steel. Extensive experiments had been made to determine the proper degree of tension for these rings, because on that point depended the efficiency of the gun. If the rings were too tight, they burst before the central part; and if they were too loose, the central parts burst first, and perhaps left the rings whole. He did not think that any limit could be assigned as to the size which would be reached in the manufacture of guns. The whole question of armor hung on the cannon which it had to resist. He had read that Sir W. Armstrong was engaged in the manufacture of a 300 lb. gun. He (Capt. Blakely) was trying to make a 600 lb. pound gun, and by using wire he did not think there was any insurmountable difficulty in making a 6000 lb. gun, or even a 60,000 lb. gun. He believed it could be

done, and if it could be done any where it was in England. The construction he would propose was that to which Sir William Armstrong alluded and approved of on the previous day, the coiling of steel wire round a central cylinder. With a 600 lb. gun of this construction the iron plates would have no chance.

The Chairman remarked that they had better confine their attention to the 200 lb. gun, which was all they had got at present.

Capt. Blakely admitted that with the 200 lb. gun the iron plates would have the best of it. He had offered over and over again to make a gun of the description he had named at his own expense, and place it at the service of the government for trial, and the offer had been refused. With all respect, he must remark that it was not philosophical for the government to refuse his oft-repeated offer, and to go on building ships with the conviction that such guns could not be made. He, however, announced that since the last meeting of the Association the Ordnance Select Committee had acknowledged the correctness of his theory that in building up cannon each layer must have a definite strain; he therefore asked the meeting to place some confidence in his assurance that guns could and would be made to smash any armor-plate which a ship could carry.

Mr. Fairbairn, President of the Association, as one of the Committee (of which Sir J. D. Hay was chairman) appointed to conduct the experiments at Shoeburyness, gave some of the results of the experiments made. Apologizing for his not having been able to prepare a written report, he stated that one of the results of the experiments made was to convince him that, though we had very good iron in this country, yet he did not think that the quality of the wrought iron was quite so good as some produced in other countries. The iron itself was good, but it had not that uniformity of texture which was obtained in foreign countries. Our iron-masters, he believed, were bestowing attention on the subject, and in a short space of time would, he believed, be able to produce such plates as would have a fair chance of resisting such artillery as Sir William Armstrong's. It was the intention of the Committee to do every thing they could to resist Sir William Armstrong, and he on his part would of course do every thing he could to smash them up. In the case of armor-plated ships, it was not only necessary to have plates of sufficient thickness, but to have sufficient resistance behind to resist the deflection caused by the shot. In the *Warrior* and the *Black Prince* wood was used for this purpose. His own opinion was, that wood was entirely unnecessary, and that every part of the vessel above the water-line would be better of iron. Experiments had been made to test the velocity of the shot from the Armstrong gun, and it was found to be about 1100 feet per second. Mr. Fairbairn referred to the necessity of securing toughness and homogeneousness in the plates, and also the desirability of securing a better mode of attachment than the present system of using bolts or screws. They had tried experiments with a target composed of iron bars; but they found that the resistance offered was not nearly so great as by the iron plates. The experiments would be continued, and

in a few months the Committee hoped to arrive at a definite result with regard to the proper thickness of the plates, the mode of attachment, and the quality of the iron.

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"On the IRON-CASED SHIPS OF THE BRITISH ADMIRALTY," by E. J. Reed.—He enumerated and described the vessels at present constructed; and stated that the construction of six other vessels had been determined upon, the contracts for three of this number having already been issued. It was important to observe that, notwithstanding the long delay on the part of the Admiralty before they commenced the construction of vessels of this class, the determination of Parliament to have a fleet of iron-cased ships had even now overtaken the Admiralty, and no experiments on a large scale had yet taken place. The great expense it would be necessary to incur to conduct target experiments on a large scale had probably much to do with the delay. A committee of eminent ship-builders had lately estimated that the cost of a target large enough to test half a dozen modes of construction would be no less than £45,000, and another £45,000 would have to be expended in the construction of a floating hull on which to place the target. The three new ships in course of construction would be 20 feet longer than the *Warrior*, 15 inches broader, 582 tons additional burthen, and 1245 tons additional displacement; and as the displacement was the actual measure of the ship's size, they would thus be more than 1000 tons larger than the *Warrior*. As the engines of the new vessels were only to be of the same power, their speed would probably be much less than that of the *Warrior*. This diminished speed was one of the penalties we must pay for clothing both extremities of the vessel with iron plates. Another penalty would probably be a great tendency to chop and plunge in a sea-way. The cost of these new vessels would exceed the cost of those of the *Warrior* class by £20,000 or £30,000. They would certainly be noble specimens of war ships. A vessel built throughout of iron, 400 ft. long and nearly 60 ft. broad, enveloped from end to end in armor impervious to all shell and to nearly all shot, furnished with the most powerful ordnance, with ports 9 ft. 6 ins. above the water-line, steaming at a rate of 12 or 13 knots an hour, would indeed prove a most formidable engine of destruction. If the present intentions of the Admiralty were carried out, we should have six of such vessels added to the navy in the next year or two. In vessels of this kind all beautifying devices must be dispensed with. Their stems were to be upright, or nearly so, without that forward reach, the "knee of the head," which added so much to the beauty of the present vessels. Their sterns would also be upright, and as devoid of adornment as the bows. It should also be stated, as a distinguishing mark of these six ships, that their thick plate would not be extended to the bow at the upper part, but would stop at the junction with the transverse plated bulkhead, some little distance from the stem, and this bulkhead would rise to a sufficient height to prevent the spar deck from being raked by shot. They would be armed with fifty 100-pounder Armstrong guns, forty on the main deck and ten on the upper. It was

not yet determined, he believed, whether these new ships were to be backed up with teak, as in the previous ships, or whether the plates should be 6½ inches thick, without wood. This would not be decided upon until after the termination of the experiments with the large targets suggested by the President and others. All that was yet definitely determined was, that whether the armor be made of iron alone or of iron and wood, its weight should be equal to iron plates 6½ ins. thick. He now came to notice a very different class of vessels, of which the hull was mainly timber with armor plated upon it. The *Royal Alfred*, *Royal Oak*, *Caledonia*, *Ocean*, and *Triumph* were all vessels of this class. Their length was to be 272 feet, breadth 58 feet, and displacement 6839 tons. Each would be fitted with engines of 1000 horse power. They were formed with timber originally designed for wooden line-of-battle ships, but had been lengthened 18 feet. The whole of these ships, it was believed, as well as the iron-plated ships, would match *La Gloire* in speed, provided they were fitted with the engines at first proposed. It was necessary to make this proviso, because there was a probability of smaller engines being put into some of them. He could not pretend to compare the French and English ships with each other in detail; but he might mention that a friend of his, who had just returned from France, had furnished him with the dimensions of the *Solferino*, one of the largest of the French iron-cased ships, as follows:—Length 282 feet, breadth 54 feet, draft of water 26 feet, burthen 6820 tons. The vessel will be plated with 4¾ inch plates, right fore and aft at the water-line, and over two decks amidships. With reference to the cost of iron-plated vessels, Mr. Reed said that, assuming the average cost of the ships to be £50 per ton, and the engines £60 per horse power, then the eighteen ships which we were now building would cost about £4,700,000, and their engines above £1,150,000—together nearly £6,000,000 sterling; and when masted, rigged, and fully equipped, £8,000,000 would have been expended upon them. He referred, in conclusion, to the extensive dock changes which this revolution in ship-building rendered necessary, and urged the serious importance of at once supplying increased dock accommodation in the South of England for these ships. He argued that whether in peace or in war such accommodation would be required; that it would be in the highest degree perilous longer to defer the establishment of colossal docks on the Southampton Water, and in some other favorable places. At present we had no docks fitted in all respects to receive such ships, whereas the French had many. Mr. Reed contrasted the English and French docks; and stated that it had been proposed to increase the French works by the establishment of an immense steam arsenal, protected by a series of impregnable fortresses at Lezardrieux.

A vote of thanks to the readers of the papers, proposed by the Chairman, was carried by acclamation.

Sir J. D. Hay rose, at the request of the President of the Association, to supplement his remarks on the Experiments at Shoeburyness with some observations of his own. The Committee, he said, in order

to ascertain the best quality of material, the best thickness of metal, and the best mode of manufacturing iron plates, invited the leading manufacturers of the country to place before them specimens of iron plates which they considered best adapted for the purposes required. Plates varying in thickness from ½-inch to 10 inches were sent in. The Committee found on making experiments, that the steely description of metal, that is to say, metal which had been hardened, and went by the names of semi-steel, homogeneous iron, &c., up to a thickness of ⅞-inch, possessed great resisting powers, but after that thickness, this description of metal was not so well qualified to resist a blow of a projectile as wrought iron of the best kind. This having been ascertained, another law had been pointed out to them which they were not yet in a position fully to recognise. It was that the resistance of the plating increased with the square of its thickness. Thus, if the resistance of a plate 1 inch in thickness was equal to 1, the resistance of a plate 2 inches in thickness would be 4; 4 inches in thickness 16; and 6 inches in thickness, 36. Considerable difficulty was felt in fastening the plates upon the sides of the vessels, as it was felt that all holes drilled in them were a source of weakness. Mr. Scott Russell had a plan of fastening the plates, which, perhaps, he would explain to the meeting. Their great fear was not of a solid missile being driven through the ships sides, but of the possible materials the shot might contain. They could scarcely hope effectually to exclude cold shot, but they did think it was possible so to construct a ship and so to plate it, that a hollow missile impinging upon its sides would be broken to pieces, and consequently they hoped to be able to exclude all shells, red-hot shot, and shot filled with liquid iron, which were amongst the most terrible weapons of modern warfare. In the course of their experiments they had tried the effect of the shells upon an old brig, the *Hussar*. At the twelfth round the brig was on fire beyond the possibility of extinction. He thought it a misfortune that the stem and stern of the *Warrior* were not better protected—and the steering apparatus was placed in that part of the ship from which the missiles were scarcely excluded at all. He thought it a wise determination on the part of the Admiralty to convert the wooden line-of-battle ships laid down into armor-plated vessels of great size and speed. In the course of the Shoeburyness experiments they had found that at whatever angle the targets were placed, the fracture made by the Armstrong gun was just as large, though it differed somewhat in shape, according to the angle. He could only account for this fact by supposing that the damage was done by the instantaneous concussion, and not by the shot boring or punching a hole through.

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Mr. T. Aston read a paper "On Elongated Projectiles for Rifled Fire-arms."—After alluding to the improvements that have been made in war projectiles, which have resulted in the elongated form, he proceeded to notice the advantages which it possesses over the old spherical shape. The elongated projectile, presenting to the resisting atmosphere a sectional area considerably less than the sphe-

rical of the same weight, is less retarded in its progress through the air. It follows, therefore, that although the spherical projectile with a similar charge of gunpowder is more easily set in motion, and has a greater initial velocity than the elongated form, and to that extent has at the outset an advantage, the elongated form is much better able to overcome the resistance of the atmosphere, and owing to its superiority of momentum preserves its progressive power for a much longer period, at the same time it is less disturbed by the varying conditions of the elastic medium through which it is propelled. In short, it has a longer and truer flight. The essential condition to the efficiency of the long projectile is, that it shall move onward with its point foremost; if it turns over in its path, it presents a large surface to the action of the air, its flight at once becomes irregular, and is rapidly retarded. The action of the common spinning-top suggests at once the idea that the best mode of making the elongated projectile move steadily through the air with its point foremost is to give it rotation round its axis of progression. The rapid revolution of the body causes its inherent inequalities to be rapidly carried round a constant axis in regular order, and a kind of balance is thereby established, which gives the body a steady motion. Various plans have been from time to time tried with the object of imparting to long projectiles a steady flight; they have been made with spiral grooves cut externally on their periphery, or internally from front to rear, in the expectation that the resisting action of the atmosphere acting on the inclined surfaces would give the requisite spinning motion. Again, they have been made very long and furnished with fins or feathers, in order that they may be propelled on the principle of the arrow, but no practically successful results have as yet brought projectiles of this kind into use. The required object is, as is well known, readily and successfully effected by propelling the elongated projectile from a rifled barrel, that is, a tube having its interior made of such a spiral form that the projectile while it is propelled from the breach to the muzzle is turned round its axis of progression: a rotary motion is thus imparted, which is retained by the advancing projectile and gives it the required steady motion. The elongated bullet was first used with rifled small-arms, either poly-grooved or fluted, or, like the Enfield, having three grooves. The length, however, was limited; and various attempts were made to fire longer projectiles compounded of various metals and of various shapes, so that by changing the position of the centre of gravity they might be propelled point foremost. But if made beyond a certain length, they were always found to turn over at moderately long ranges. Mr. Whitworth was the first to enunciate the principle that projectiles of any requisite length could be successfully fixed by giving them rapid velocity of rotation, which should be increased in proportion with their increased length. He, as is well known, uses rifles having a spiral polygonal bore, in which all the interior surfaces are made effective as rifling surfaces. The success of the elongated projectile having been established in the case of small-arms, their employment with ordnance followed as a natural consequence. Rifled ordnance were, therefore, called into existence to meet

the requirements of the time. In fact, the rifled cannon may be considered as a rifled musket made with enlarged proportions. Directing our attention more particularly to the two systems of Armstrong and Whitworth, we see in the former the coiled barrel and fluted bore formerly used for the rifled small-arm, applied on an enlarged scale. In the Whitworth cannon the same system and form of rifling are used which are employed for the Whitworth musket. There is, however, a change required for the projectiles; they cannot, like the small-arms bullets, be made of lead, for obvious reasons, such as the cost of metal, its liability to distortion of form, and unsuitableness for shells. Sir William Armstrong uses a compound projectile, formed of an iron case surrounded with a leaden coating,—the rifling being effected by the force of the explosion in the barrel, which is thus partly expended in forcing the lead through the grooves. Mr. Whitworth uses a simple hard-metal projectile, made of the requisite shape to fit the rifled bore by machine labor in the manufactory, so that the whole force of the explosion is employed to propel the projectile. After giving a description of the two projectiles, and pointing out that the Armstrong projectile necessarily required a breech-loading cannon, and that the Whitworth is used at pleasure for muzzle-loading or breech-loading cannon, Mr. Aston proceeded to notice the external shape of the projectiles. The importance of giving to ships intended for high speed the shape best suited to facilitate their progress through water is now universally acknowledged; and Mr. Whitworth considered that it was necessary to ascertain, by reasoning upon similar grounds, and by experimental research, what was the proper shape to give to his projectile, so that it might be propelled through the air under conditions most favorable to precision and range. He, after numerous corroborating experiments, decided that the projectile of the form exhibited to the meeting was the best. It has a taper front, having nearly the external section of what mathematicians term the solid of least resistance, the curve being somewhat rounded; the rear is made to taper in such proportion that the air displaced by the front is allowed readily to close in behind upon the inclined surfaces of the rear part. The middle part is left parallel to the required distance, to provide rifling surfaces and obviate windage. The results of long and repeated trials show that this form of projectile gives much greater precision and a superiority of range, varying from 15 to 25 and 30 per cent. (according to the elevation and consequent length of range), as compared with a projectile of the common rounded front and parallel rear end. At low elevations, where the range is comparatively short and the velocities great, the difference in the result of the taper and non-taper rear is not so marked as at the higher elevations, where the mean velocities of the projectiles are reduced. But at all ranges the superiority exists both in precision and velocity, as the elongated projectile at no practical range has a mean velocity so great as to prevent the atmosphere closing in behind it. One of the most important advantages attending the use of the taper rear is, that it gives a lower trajectory, which renders errors in judging distance of minor import-

ance, as the projectile which skims along near to the ground is more likely to hit a mark, especially a moving one, than a projectile which, moving in a more curved path, has to drop, as it were, upon the object aimed at, whose distance therefore must be accurately guessed. The taper shape of the rear is peculiarly well adapted for the proper lubrication of the gun, which is most essential for good shooting. With the Whitworth gun a wad made wholly of lubricating material was introduced; it obviates the necessity of washing out the piece,—and the subsequent adoption of a similar wad for the Armstrong gun enabled that piece also to be used without washing out, which was at first necessary, and found to be a very inconvenient operation for a service gun. Various forms of elongated Whitworth projectiles suited for special purposes were described: tubular projectiles for cutting cores out of soft materials, as the sides of timber ships; flat-fronted hardened projectiles, first used by Whitworth and afterwards by Armstrong, for penetrating iron plates. It is found that these projectiles penetrate, when fixed point blank, through iron plates inclined at an angle of $57\frac{1}{2}°$* to the perpendicular. The edge of the flat front, though slightly rounded, takes a hold, as it were, as soon as it touches the plate, and the resistance met is merely that due to the thickness of plate measured diagonally. Official experimental trials made on board the *Excellent* at Portsmouth showed that these projectiles penetrate readily through water, and would go through a ships side below water-mark. The new American floating battery, which is submerged to protect her sides during action, would find no defence in that plan against these projectiles. Shell and shrapnel having the elongated form and taper rear were also described; and to show the suitableness of that form for ricochet firing, tables were read, from which it appears that the mean results of a series of six shots, making many ricochets within a range of 2400 yards, gave the greatest mean deviation of about 75 yards from the straight line. In considering the probable result of the contest now going on between armor-plates and projectiles, it should be borne in mind that the limit of thickness of armor-plate that can be carried by ships will soon be reached, but that the power of destruction of projectiles may be without doubt increased far beyond what has hitherto been tried. It may, therefore, be reasonably anticipated that in this all-important contest the victory will ultimately rest on the side of the projectile.

Sir W. Armstrong said that, with regard to the prospective size to be attained in the construction of artillery, he must confess he did not go so far as Capt. Blakely. It was quite true that he himself was engaged in the construction of a 300-pounder gun—and the experiment was already very considerably advanced, and so far with perfect success—but, at the same time, he must say he found the construction of even a 300-pounder gun on his principle a work of considerable difficulty, and he really would venture to suggest to Capt. Blakely that it would be better to obtain a 100-pounder or a 200-pounder before he

* Sir J. D. Hay subsequently confirmed Mr. Aston's remarks in this respect, and said that Whitworth flat-fronted shot fired from an Armstrong gun (for the Armor-Plates Committee) had penetrated plates inclined at an angle of 30° to the perpendicular.

ventured upon such a monster as he had mentioned. He agreed with Capt. Blakely that the hooping of a cast iron gun with wrought iron gave it great resisting power; but he differed from Capt. Blakely in thinking that such mathematical nicety was required in the construction. Provided only care were taken to allow sufficient shrinkage, the hoops would adapt themselves to that amount of tension which would give the maximum resisting force of the gun, and before the hoops would give way the gun would have passed through the phase of greatest resistance. He entirely agreed with Mr. Fairbairn as to the desirability of adopting the form of structure for plated ships which should obviate the use of wood. He attached great importance to this plan, because by adopting it much unnecessary wood would be got rid of, and the iron plates could therefore be thickened, but chiefly because by this means the liability of part of the ship rotting, and their having to pull it to pieces periodically to set it to rights again, was done away with. His opinions on the subject of iron-plated ships had been so often made known that it would be mere repetition for him to go over the ground again. The only new point he had to bring before them was, that in the construction of those ships they must chiefly keep in view their adaptation for a small number of monster guns. There had been a feeling among naval men that guns above a certain weight—five tons, he believed—could not be practically managed on board ship. Lately, however, their ideas had been considerably enlarged, and they now went as far as 7½ tons, which would be about equal to one of his 200-pounders. He believed that guns of a much larger size could be managed, but to do so of course they would have to avail themselves of machinery. Mr. Aston had explained the Whitworth projectile, and had called attention to what he considered it various merits. He had also alluded to his (Sir Wm. Armstrong's), which lay on the table before them. Upon this subject let them talk as long as they liked, Mr. Aston and himself would never come to an agreement. He believed that his own projectile would inflict a greater amount of damage than the other. He thought something more was required than the punching process of the flat-headed shot. Let the effects be tried. Let a target be erected representing an object such as would be used in actual war, and then let experiments be made to see which missile would inflict the largest amount of injury. He had no doubt whatever, that for punching a hole in iron plating the flat-headed bolt invented by Mr. Whitworth was the form, if made of steel. But he apprehended that the object to be attained was not only to punch a hole in the side of an armor-plated ship, but to inflict so much damage as to disable her. What he wanted to effect was to be able to hurl a large mass, no matter what form, against the vessel, so as to crush in her side, and he believed that this could be done by the use of guns of a large size. In the Whitworth projectile, the rotary motion was given by the shape of the bolt. In his own ordnance the projectile was covered with a soft material, and so took the direction of the grooves. There might be advantage in both plans; but he did claim for his own this superiority, that there was less necessity for precision in the manufacture, and

little fear of injury to the bolt. He had lately been making experiments with a large kind of projectile, one of which he had before him, [a huge mass of metal, weighing some cwt.] In this projectile, instead of having a soft metal all round it, it was confined to three ribs, which would take the impression of the grooves. It was designed for a gun called the "shunt gun," the construction of which, not having a diagram with him, he could not explain.

Mr. J. Scott Russell said, there were one or two general considerations of this subject which he thought, if laid before the meeting, would save a good deal of misapprehension. If they would just set out by believing that we should never get perfect impenetrability, many schemes, with the answers to them, would be put out of the way. The whole practical part was incorporated in one expression of a great sailor, "Whatever you do, for God's sake, keep out the shells." Having been in vessels fired at, and having been behind iron targets fired at, he was in a position to say that he could stand behind iron plating with a wonderful degree of comfort. You were sure the shells would be kept out, and if two or three holes were punched, in the side of the ship by the large shot, neither you nor the vessel were much the worse for it. But if Sir William Armstrong should be able to do as he had just said, to bring large masses to bear upon the sides of these iron-plated ships, then this was another mode of destruction quite as injurious as destruction by shells would be. The whole question then resolved itself into these two things:—Keep out the shells, and prevent Sir William Armstrong driving in the sides. The ship-building question at the present time involved the very difficult problem, how to build a ship with an enormous weight in the place where good shipbuilders generally contrived to keep out all weight. The first vessels were loaded with 1000 tons, the new vessels would have 1500 tons, and this weight was not only a great inconvenience, but a great injury to the sides of the ship. As the ships were now built, the plating in no way contributed to the strength of the ship; he was anxious to see the ship built entirely of iron, in which case iron plating might contribute to the strength. What he wanted to know was, how much in the construction of these large ships the builders might be allowed to appropriate of 9 inches of iron to be used partly in armor, and partly in the construction of the ship? The question they now asked the Iron-Plates Committee, and which he believed Mr. Fairbairn's experiments would settle in a very short and decisive manner, was, how much of this iron could be used in the construction of the ship, and how much must be used in armor-plating outside? Take it that there were eight inches of plating allowed. If the Committee would be content with a 2-inch plate, and a 1-inch plate on the outside, leaving the builders five inches to be used in the sides of the ship, he was prepared to say that this would be an enormous advantage. He would even meet them further, and give them four inches to be used for the armor, leaving him four inches to be used in the construction of the ship. But the Committee might insist upon having a 5-inch plate to go to the bad, leaving him only three inches for the ship, and he would

still endeavor to build the ship to suit these conditions. There was another point upon which the builders were at issue with the Committee. The Committee say they will not have holes in these iron plates, and the builders reply that, so far as they knew at present, the Committee must have holes. Sir J. D. Hay had asked him to lay before the Section a plan which he had submitted to the Admiralty so long ago as 1854. He would bring up between the plates a piece of soft malleable iron. This he would heat in its place after the plates were on, so as to make a round-headed rivet all round the edges of the plates, which could thus be firmly attached. This plan, if successful, would obviate the necessity of perforating the plates; but allow him to say that he did not believe in his own opinion until tried, for there was scarcely a theory promulgated but was knocked down by those Armstrong and Whitworth guns—and at the present moment he had not a single theory to set up. The *Warrior* had been built without armor on her extreme ends, and he (Mr. Scott Russell) had some of the blame or the merit of that arrangement—which it was, remained to be seen. But yet he would take very little credit on that point, for this reason, that when the dimensions and the required speed of a vessel were settled, the question as to whether she should bear armor from end to end was determined beforehand by the very conditions of the problem. Referring to Mr Aston's paper, Mr. Russell entered into calculations to show why he did not attach much importance to the tapering form of the Whitworth projectile. He believed that in proportion as the velocity of the projectile was less than its critical velocity, which he believed was about 1100 feet per second (the very velocity which the Committee had ascertained was the velocity of the Whitworth projectile), in that proportion only might some advantage be derived from distinction of shape. The case of the projectile and the ship differed in this, that the one had attained its critical velocity and the other had not, hence this difference in his opinion with regard to the value of form. In the ship it was of value, but in regard to the projectile which had attained its critical velocity, length and fine taper would have no effect. But this was one of the subjects upon which no wise man would dogmatize, but would be grateful to any one who would institute experiments. Admiral Sir E. Belcher considered that the suggestion of Dr. Eddy, for constructing small vessels to compete with the iron-cased frigates, had been met by Mr. Scott Russell's observations on the incompatibility of weight and speed without dimensions. The height of the large vessel would enable her so to depress her guns that the smaller boat would present an angle of about 60°, instead of the angle stated. The curved deck of the proposed gunboat involved the necessity of its being rendered bomb-proof, and that entailed iron plating equal to the plating of a frigate. The fibre suggested for the packing would be peculiarly liable to smoulder or to burn, and the salt with which it was proposed to render it incombustible would corrode the iron so rapidly that, in the course of a few months, the vessel would be useless. It had occurred to him, that in-

stead of the iron plates being backed up with wood, iron ribs, placed transversely, something in the gridiron fashion, at intervals from each other less than the diameter of the shot, and the interstices filled up with wooden material, would be a better mode of resistance. By the present system of laying the iron plates, if one were injured when the vessel was abroad, it would be impossible to replace it, perhaps for months or even years. Therefore he thought it would have been better if Mr. Scott Russell had followed out his plan of sliding the plates in from the water-line upwards, because if one of the lower plates happened to get injured, it could be removed, and the other plates could be slid down to fill up the vacant space, and a new plate could be put in at the top without difficulty. After the battle of Algiers, it was his duty to clean out the captain's cabin. He was surprised to find that a ream of foolscap, which had been struck by a large shot, had simply been crimped up. In 1854, he applied for leave to build a battery of compressed brown paper, and he believed that this material, which was one of the most powerful repellants of shot, might be advantageously used. Sir E. Belcher alluded to the force with which even wooden ships could charge and split icebergs, and expressed his decided opinion, that if the weight of the *Warrior* struck *La Gloire* across the bows, the latter must inevitably go down. He, himself, if hard put to it, should have no objection to have a try at *La Gloire* in one of the old wooden ships—and he thought he saw some of his naval friends around him who would say the same. He complained that the peculiar construction of the new vessels would deprive them of the pleasure of running down an enemy, which was a point upon which naval men prided themselves.

The Rev. Dr. Robinson (Dean of Armagh) said the paper which had been read by Mr. Reed, could hardly be rated too highly, and he hoped a recommendation would proceed from that Section that it should be printed in the *Transactions*. In the course of an interesting address, Dr. Robinson traced the invention of armor-plates to Lord Rosse; and whilst paying a high tribute to the splendid mechanical genius of Mr. Whitworth, he pointed out that both the elongated projectile and the beautiful system of polygonal rifling were inventions dating much further back than his time. He himself had seen a rifle on the polygonal principle, made two centuries before Mr. Whitworth was born.

Mr. Fairbairn, in allusion to the remarks of Mr. Scott Russell as to the possibility of using a number of single inch plates, instead of one solid plate, stated that the experiments had shown that one 2-inch plate was equal to three or four 1-inch laminated plates. He quite agreed with Admiral Belcher as to the form of the bows of the *Warrior*. His own opinion was, that they should have been curved downwards instead of projecting below.

MECHANICS, PHYSICS, AND CHEMISTRY.

Hydraulic Power.

From the Lond. Mechanics' Magazine, Sept., 1861.

A wonderful example of what hydraulic pressure, acting through suitable machinery, can effect, is seen in the application of what is known as Sir W. Armstrong's hydraulic apparatus at the Swansea Docks. The pipes which convey the water, at a pressure of 700 lbs. to the square inch, extend for a mile and a half; the hydraulic power being available at any point throughout this length. By this agency, rendered so docile as to be almost within the control of a child, though before it the strength of the elephant sinks into insignificance, the gates are opened, the bridges swung, the sluices worked, and all the herculean labors of the docks performed. Man, no longer a mere drudge, exhausting his puny strength in endeavoring to counteract the forces of nature, employs these forces one against the other, and renders them obedient to his will. Mechanical science first taught how power might be gained at the expense of speed: the steam engine and the hydraulic press were an advance beyond this point of compromise, placing unconditionally in the hands of man, a power which can scarcely be calculated as a multiple of a man's work in foot-pounds.

The only important practical objection to the universal employment of the stupendous power of hydraulic pressure wherever it may be made available, is the danger arising from the necessary steam apparatus erected in the vicinity of warehouses; in consequence of which, increased rates of insurance become chargeable. To remedy this objection, it has been proposed to establish central stations for the generation of hydraulic power, and to distribute this by means of mains laid along the principal thoroughfares in proximity to wharves and warehouses, to which the power required for working cranes and hoists, or for any other purpose, would be conveyed by branch pipes. Thus a motive power of any amount, certain in application, and under perfect control, would become available, with the advantage, in point of safety and economy, of dispensing with separate steam power for each establishment.

The full importance of the results which would follow the application of this system, are but partially shown in an arithmetical statement giving the mere pecuniary *saving* in actual hoisting. The speed with which the work can be done, and ships or barges loaded or cleared to make room for others, is a most important element in the calculations of the owners of wharf properties. Under the present system of manual labor applied to cranes and hoists, lifting forty tons through forty feet in twelve hours, by the employment of six men, must be considered a good day's work for the latter. The cost per ton in this case would be between 6d. and 7d.; whereas by hydraulic power, 200 tons could be raised to the same height, in the same time, at a cost of about $1\frac{8}{10}$ths of a penny per ton.

The simple arithmetical statement shows that the cost of the present

system varies from one halfpenny per ton per foot, for a "short lift," to one-sixth of a penny for a "high lift;" this being the actual cost of labor, without taking into calculation the interest of capital invested in machinery. By the application of hydraulic power under the proposed system, the cost of raising one ton one foot high is reduced to ·06d., or about one-sixteenth of a penny; allowance being made *at the rate of twenty-five per cent.*, for the interest of the capital necessary to establish the mains and the entire working machinery. At the Liverpool docks, the comparative expenses of the two systems have been calculated by Mr. Hartley, as bearing the proportion of eight to twenty-two in favor of hydraulic power.

The amount of work performed by the hydraulic crane may be estimated by an inspection of the St. Catherine's Docks; where one crane, of double power, raises from the vessels to the quay, 370 tons in seven working hours. At the Regent's Canal, the coal cranes discharge upwards of 300 tons in ten working hours, raising from seven to eight cwt. of coal at each lift.

There is another point of view in which the project we have alluded to may be regarded, viz: as affording an extremely adequate safeguard against fire. It has already been shown that the advantages which are offered are accompanied by no danger arising from a furnace and steam boiler on the spot where the hydraulic power is to be applied. But in case of emergency from fire, the supply of water under high pressure may readily be made available for its extinction. Recent calamities, which we need not particularize, have sufficiently proved that the class of buildings to which the project applies are peculiarly liable to the devastating action of fire; and at the same time these calamities have rendered evident the inefficiency of the means now at hand to guard against such danger. To obviate inconvenience from any accident to one set of pipes, a double main will be laid to convey the hydraulic power; and to one or both of these a hose connexion will be established at each set of premises using the power. This hose connexion will be kept closed and sealed until such emergency arises, as to render the water supply by this means indispensable.

Those of our readers whom this project specially regards, may be glad to learn that there is every prospect of its speedy accomplishment. The requisite Parliamentary powers were obtained last year for the formation of a company to carry the same into effect. The plan of operation includes, in the first instance, the establishment, on both banks of the Thames, below Blackfriars-bridge, of a sufficient number of cranes, worked by hydraulic pressure, generated by two steam engines placed at central points for that purpose. The facilities which will thus be afforded for the traffic operations on the great river thoroughfare to the metropolis will not fail to be appreciated; and the same facilities will doubtless before long be extended throughout the kingdom. On the part of the offices for insurance against fire, there appears to be every disposition to lower the present rates of insurance for premises in which the proposed means for obtaining motive power and the supply of water under pressure may be adopted.

For the Journal of the Franklin Institute.

Reply to the Criticism of SAMUEL MCELROY, C. E., "*On the Erie Experiments on Steam Expansion by U. S. Naval Engineers.*" By ALBAN C. STIMERS, Chief Engineer, U. S. Navy (one of the Experimenters).

The paper, of which the above quotation is the title, appeared in the October and November numbers of this *Journal*, and is a remarkable example, no less of the looseness with which many engineers read professional papers, than of the great want of analysis they bring to bear upon the subjects of which such papers treat. It is well, perhaps, that such a reader and such a student should have given us the impression which the report of the Board made upon his mind, as he is the representative of a large number in the profession, who exercise in their numerical strength a great influence over the designs and proportions of a large amount of steam machinery. A reply, therefore, to one of them, who has had the boldness, the intelligence, and the literary ability, to come out and attack the report in a first-class magazine, though it may not be a reply in detail to each individual, will at least have the effect of showing them that a closer study of the report itself would answer most of their objections.

The following are some of the principal difficulties under which this writer labors:—

A failure to conceive the real matter which the experiments were intended to assist engineers in deciding.

A failure to separate incidental information, developed in the course of the experiments and generally valuable to engineers, from that which bore directly upon the main question to be decided.

A misconception of what the conditions are in an engine, the change of which will affect the economic result. And finally,

He fails to comprehend many of the simplest arguments, and to perceive that most of his objections are answered in the body of the report itself.

He says, "This is the real matter at issue—whether it is cheaper to carry high steam and expand, or to carry low steam and follow full stroke." He does not appear to be conscious that this mode of regarding the subject unites the question of high pressure with that of expansion; whereas, the experiments were instituted, not to ascertain the relative economy of using steam of different pressures, but "the relative economy of using steam with different measures of expansion." The report states, on page 23, in the very commencement of the "discussion of the results," that, "In examining the preceding two tables, it will be observed that particular care was taken to have the initial cylinder pressure (table 2, line 1) the same in all the experiments, as nearly as practicable, which, with proper area of conduit open in proportion to quantity of steam used in equal time, would necessarily make the boiler pressure equal. In fact, throughout the experiments, the boiler pressure (table 1, line 18) was nearly equal, the difference

being too slight to be of any practicable importance. That this is a proper condition for the purpose of the experiments will be obvious when it is considered that amount of pressure is purely a question of boiler, and not at all one of engine.

"If a given power be required to be developed by the same piston, working at a given speed, but with different measures of expansion for the steam, it is plain that the initial pressure must be increased as the steam is used more expansively, and the condition of equality of initial pressure could not obtain. This, however, would only be unnecessarily employing too large a cylinder when the steam was used less expansively; or, in other words, it would be an engineering blunder. The proper method is—for equality of power and of initial pressure—to proportion the cylinder to the measure of expansion adopted for the steam, making its capacity for equal speed of piston inversely (table 2, line 22) as the net effective pressures upon the piston (table 2, line 7).

"From the justness of these premises there is no escape, and it is preposterous to base a claim of economy for large measures of expansion, not upon the expansion *per se*, but upon higher initial pressure, when that same pressure can be employed just as easily and well when using steam without expansion, if the cylinder be properly proportioned to the work. Therefore, in making a set of experiments to determine the *practical* economic results of using steam with different measures of expansion, it is an *essential* condition that the initial cylinder pressure be maintained the same in all cases.

"It is now proper to give the reasons why a high initial pressure is desirable in view of the economical production of the power. And, first, of the generation of the steam.

"As the dynamic effect of a given weight of steam increases in a higher ratio than the heat required to evaporate it—owing to the accompanying increase in the temperature of the steam—it is obviously desirable to use it in the cylinder at the maximum pressure throughout the entire stroke. We say *use* it in the cylinder, for the economy in function of pressure *per se* attaches to the pressure under which the steam is used, and not to that under which it is generated, because its dynamic effect is developed during its use in the cylinder, and not during its generation in the boiler. Now, it is plain that, starting with the same initial cylinder pressure, the steam will be used with the highest pressure throughout the stroke of the piston when it is used without expansion; and the more it is expanded, the more is the pressure reduced in the cylinder, and the advantage lost that attaches to higher pressure *per se*. This is one *practical* point of gain for smaller measures of expansion over larger ones—a point entirely ignored when the problem is merely theoretically considered, but which must be included in a practical determination; because it is an inseparable function of the physical laws of steam."

The careful reader will observe as very prominent in the foregoing quotation from the report of the Board, that they were not endeavoring to ascertain how much it was desirable to expand the steam in

existing engines, but in those which were yet to be built, and in which proportions could be given that would do the required work in the most economical manner; that the question of expansion, as separated completely from that of boiler pressure, was the subject of investigation; and that they recognised fully and stated clearly the advantages of high pressure steam.

This writer discusses the rate of combustion in the furnaces, the evaporation per pound of coal, the pounds of coal per hour per horse power, the order in point of time in which the different experiments were tried, the speed of the piston, the amount of steam used in a given time, &c., &c. If these questions affected the economic result as properly ascertained by accurate measures, it would be very proper for him to discuss and criticize them; but he does not even attempt to show that they influence in the slightest degree the only measure of the cost of the power developed by the engine, which was pronounced as the only correct one by the Board. They state, page 31 of the report,—

"With regard to the cost of steam power, there are three different measures in use, all of which will be found employed in table No. 1: namely, the weight of the coal; the weight of the combustible; and the weight of water, by tank measurement, consumed per hour per horse power. The last alone is employed in table No. 2. Of these, the first is the least exact; the second is more exact than the first, because it eliminates the ashes, the amount of which is an accidental quantity; but the last eliminates everything connected with the generation of the steam, and is, therefore, critically exact, and should be accepted as the true, universal, and only measure of the cost of the dynamic effect, *per se*, produced by the steam in the cylinder."

It will be perceived that, with this measure accurately applied, it would add nothing to the reader's information upon the subject under discussion, "to have known precisely the times and manner of coal supply, tank supply, cleaning fires, starting and hauling fires, variations of pressure, and the like, as to the boilers."

To show that the Board recognised fully the effect upon the evaporative powers of the coal, of the change in condition to which it was necessary to subject that part of the apparatus in order that the essential one should remain unchanged, I quote from the report what immediately follows the above explanation of the true measure of *engine* economy.

"The weight of coal, under the most favorable circumstances, can only be considered as an indirect and comparative measure of the weight of steam consumed; but, even comparatively, it is not exact unless all the conditions of boiler and coal continue precisely the same, which is a manifest impossibility, as the calorific effect obtained from the coal varies with the skill and care of the fireman; with the quantity of water mechanically present in it; with the temperature of the air entering the ash-pit; with the rapidity of the combustion; with the thickness of the fuel on the grates; with the hygrometric and barometric conditions of the atmosphere; with the more or less copi-

ous supply of air to the furnaces; with the temperature of steam in the boilers; and with the per centum of refuse obtained from the coal; not to include the uncertainty in the determination of the precise weight of coal which generated the steam used in the engine."

The intelligent reader will observe, then, that all the long drawn-out discussions of this writer about the rate of combustion; the use of different coals with their attendant differences in per centa of ashes, &c., and their different evaporative powers, are all thrown away. All that is merely incidental information, and does not affect the question of "the relative economy of the use of steam with different measures of expansion" in the slightest degree, when the economy of each of those measures is determined by the amount of water required to be evaporated per hour per horse power. As it is true, however, that a doubt of the propriety with which any of the information given, even though only incidental, was obtained, would throw a doubt over the whole report, it is proper to reply to some of the principal objections which he has brought against the coal account. It must not, however, be forgotten that the primary objects of the experiments were not to be interfered with in order that engineers might know exactly the evaporative power either of the coals or the boilers used. The Board very naturally expected that there should exist in the profession generally, sufficient sagacity to perceive this and consider the incidental results shown, in close connexion with the conditions under which they were obtained; all of which are fully described in the report.

He tells us that, though in the text the Board claims that "In commencing an experiment, the engine was operated for several hours to adjust it to the normal conditions required to be uniformly maintained during that experiment, and to bring the fires to steady action," the tabulated record shows that, in one case, there was no interval at all, and in two others, only two hours.

In the case of there being no interval, there was nothing to be changed, except the damper in the smoke-pipe, and the point of cutting off. It probably took *one second* to change the former, and *ten* the latter. The other changes upon which he dwells, were simply the immediate results of those two simple movements. The general statement in the text is perfectly true as a general statement intended to cover the experiments as a whole. The above happens to be an exception when it was not required to sweep the flues, change the kind of coal used, or to add to or remove from the wheels any paddles. As for the two instances of there being but two hours between two of the experiments, it must be a very firm position that it is necessary to assail by drawing the nice distinction between the general statement of "several" and the particular one of "two," occurring twice out of six times.

With regard to estimating the "efficient" amount of coal in the furnaces at the commencement and at the end of the experiments, the Board considered that in obtaining the number of pounds of coal per hour per square foot of grate; the number of pounds of water evaporated per pound of coal; or the number of pounds of coal per

hour per horse power, the last decimal place given would not be affected by any error it would make in this estimate, as each experiment was continued sufficiently long to reduce such errors beyond any change in the third decimal figure. The results as given are, therefore, mathematically accurate to that decimal, notwithstanding possible errors in such estimates.

He endeavors to make a point of the difference in the per centum of refuse obtained from the different coals used. He does not appear to be aware that different coals may contain different amounts of non-combustible material, or that different cargoes of coal from the same mine cannot be expected to contain precisely the same per centum of refuse.

It is not necessary to follow him further in his remarks about the coal. Enough has already been written to show that his positions upon it are untenable, and to refute each detail would only add to the length of this paper without increasing its force.

With regard to the corrections of the back pressures in the cylinder to the uniform one of 2·7 lbs. made in table No. 2, he says:—

"There is a difference of vacuum against No. 2, which we do not find credited. Experiment No. 7 ($\frac{1}{4}$ ths) shows an average back-pressure in the cylinder of 4·2 lbs., while No. 2 shows but 2·8 lbs. In all these trials, it appears that expansion reduces back pressure by a descending series, except a change in No. 7.* But without accepting this *experimentum crucis* of the condensation argument, the Board decides that back-pressure must be assumed at a common standard, which it accordingly takes at 2·7 lbs. from No. 3. Consequently, the mean pressure of No. 2, which is 13·6 lbs., is to be charged with the standard of 2·7, while that of No. 6, at 29·8 lbs., is credited with the difference between 4·2 and 2·7. This varies the relative horse power, and is highly creditable to the treatment of the questions at issue."

The Board made out one table as the experiments progressed, containing, complete, the exact experimental determinations; but although this is given in the report, it was considered that it would be more complete for the purposes of correct comparison, if differences, obviously due to accidental circumstances, could be eliminated. Upon this subject the report states:—

"The quantities given in table No. 1 are the precise ones obtained by experiment; but some of them require to be slightly corrected, for the purpose of making exact comparisons. The quantities to be corrected are only those of the mean gross effective pressure on the piston, and back pressure against it, (table No. 1, lines 22 and 23,) together with those of the mean gross effective, total, and net horse power depending on them (table No. 1, lines 24, 25, and 26). These corrections are made necessary by the fact of the inequality of the back pressure during the experiments; but, as it was caused by such accidental circumstances as air leakages, different proportion of cylinder steam-port to weight of steam discharged at the end of the stroke of

* He has evidently become confused in his numbering of the experiments, and intends here the one cutting off at 4-45ths.

the piston, and different speed of piston, all of which can be made the same and the back pressure rendered equal, it is necessary for a proper comparison to make the back pressure the same in all the experiments, and to rectify the mean gross effective and net pressures on the piston in accordance with this equality. This has been done in table No. 2, which contains, in addition, all the other data and calculated results requisite to a complete determination of the relative economy due to the different measures of expansion."

It will be observed in this quotation from the report, how completely the Board sank all considerations of existing engines in their search for the true principles which should govern future constructions, and as the amount of back pressure is dependent entirely upon freedom from air leakages, area of exhaust passages, and condenser and air pump capacity, all of which, in every well proportioned engine, are designed with reference to weight of steam used in a given time, and not with reference to size of cylinder, nothing can be more proper than to assume that it shall be uniform. It was obviously impossible to have it uniform experimentally without changing the structure of the engine used for the experiments; but it was considered that a matter so self-evident would only require that a proper quantity should be taken as the standard for all. It was determined to take the smallest that was experimentally obtained in any one trial; this was 2·7 lbs., and occurred in the experiment in which the steam was cut off at $\frac{1}{4}$th.

Now this writer complains that in the trial which expanded the least ($\frac{1}{1\frac{1}{2}}$ths) the mean pressure obtained by experiment is credited with the difference between the 4·2 lbs. back pressure obtained by experiment and the 2·7 lbs. taken as the standard; while the trial which cut off at $\frac{1}{8}$th has only the difference between 2·8 lbs., obtained by experiment, and the same standard of 2·7 lbs. That is, according to him, the Board gave the $\frac{1}{1\frac{1}{2}}$ths trial an advantage of 1·4 lbs. per square inch in the final comparisons. To many people it will appear quite clear that taking the lowest back pressure obtained experimentally as the standard was giving the greater measure of expansion all the advantage it could claim, as with equal initial pressures the greater the measure of expansion the less is the mean total pressure. To make it clear to every one, however, let us suppose that the highest back pressure experimentally obtained (4·2 lbs.) be taken as the standard, instead of the lowest (2·7 lbs.), and observe the difference in the comparative economy.

	As per table.		Supposed case.	
Point of cutting off, . . .	$\frac{1}{1\frac{1}{2}}$	$\frac{1}{8}$	$\frac{1}{1\frac{1}{2}}$	$\frac{1}{8}$
Mean total pressure, ...	34·0	16·4	34·0	16·4
Mean net pressure, ...	29·2	11·6	27·7	10·1
Per centum which the latter is of the former, .	85·9	70·7	81·5	61·6
Relative net pressures between the different points of cutting off, ...	1·000	·822	1·000	·756

The greater measure of expansion would therefore lose

$\left(100 - \frac{\cdot 756 \times 100}{\cdot 822} = \right)$ 8 per cent. if calculated as desired by this critic, instead of by the method adopted by the Board.

When this writer comes to the subject of the friction of the engines, he does not appear to understand that the friction of the load, varying directly as the load, may be considered as a part of it in all calculations for comparison between different trials with the same engine. It was only the friction caused by the gravity of the different parts of the engine that the Board considered constant, that is, that it required a constant pressure to overcome. So that, instead of controverting "Morin, Weisbach, and others," it was upon the general principles laid down by them, and experimentally found strictly applicable to the steam engine a few years ago by two naval engineers, that the Board proceeded.

With regard to reducing the size of the engine when the measure of expansion is reduced, he tells us that only the diameter of the cylinder would be reduced, all other parts remaining precisely the same; but it is well understood by all good designers of steam engines, that all the parts through which the power of the steam is transmitted must be proportionable to the initial pressure upon the area of the piston. With the given initial pressure, therefore, the larger piston, required when using larger measures of expansion, requires also larger piston-rods, cross-heads, connecting-rods, beams, cranks, shafts, pillow-blocks, engine frames, bed-plates, &c., &c.—condenser, pumps, pipes, and valves being the only parts that undergo no change.

In remarking upon the fact that engineers were aware before the trial of these experiments that there was a loss by steam leakages and condensation, he states:

"So fully, in fact, are engineers advised on this point, that when any experiment is presented to them, no matter by whom conducted, which claims to have found but 2·91 per cent. loss between the tank and indicator, they respectfully deny its accuracy. It is impossible to avoid a greater loss in the boiler itself, and between the boiler and steam chest, and at the valves as well as in the cylinder."

The steamer *Michigan*, in which these experiments were made, had been out of commission twelve months, during which time new boilers were put in and the engines thoroughly overhauled by one of the most experienced and careful engineers in the naval service; and, in addition to this, the Board spent two weeks in preparing everything for the experiments, taking especial care to prevent the possibility of leakage. With regard to leakage from the boilers, the report states:

"The only outlet from the boilers was through the blow-off valve. Any leakage to occur here had first to pass the blow-off valve, and next the stop-cock placed in advance of the Kingston valve. The blow-off pipe, its valves and cocks were frequently examined during the experiments, and the undersigned are certain there was no leakage from the boilers. The boilers themselves were quite new, and double

riveted; they were so tight that the water would stand in the glass gauges without appreciable fall for days."

It is considered that there will be little difficulty among engineers about choosing in which of the above explanations and assertions they will place their confidence.

His illustrations of losses by leakage and condensation, immediately following the above quotation from his paper, do not require recapitulation, as their errors are certainly too evident to deceive any reader of this *Journal.*

He complains that the notes of the experiments are omitted in the report. It would be interesting to know of what possible use it would be to engineers to have placed before them 21 pages of tabular record and the engravings of 1008 indicator diagrams. Why does he not ask for a verbatim report of all the discussions which took place daily between the members of the Board, while the report was being elaborated and written?

He concludes his paper with an elucidation of "a certain mechanical principle," which speculative engineers of slight practical experience sometimes indulge themselves in dreaming about. The "principle" being that, as the inertia of the mass—the motion of which is accelerated during the first half of the stroke and retarded during the last half—absorbs a portion of the power of the steam while being accelerated, and returns it again while being retarded, the engine will work more smoothly and properly when cutting off at less than half stroke than when following beyond that point. A little practical experience soon dispels all this kind of visionary speculation. He must certainly admit that the difficulty he predicts for an engine cutting off at a point beyond the half stroke would increase with an increase of the speed of piston. Now, it so happens that the present writer took a trip only a few days ago from New York to Amboy, N. J., and return, in the steamboat *Richard Stockton*, for the express purpose of observing the operation of her steam machinery, accompanied by the engineer who designed it. The engine is the ordinary over-head beam, and was built in 1852. The cylinder is 48 inches diameter by 12 feet stroke of piston. The average revolutions during the above trip were 27 per minute, equal to a speed of piston of 648 feet per minute, and I was informed that it had been driven at the rate of 31 revolutions, or 744 feet per minute. Probably this speed of piston is not exceeded, if equalled, by any engine of equal dimension, and it certainly worked with remarkable smoothness and regularity, yet it was cutting off at *three-fourths* the stroke from the commencement. The designer of the engine explained why he followed so far by saying, that the engine was being driven so fast it was impossible to make it work smoothly and regularly when cutting off at any shorter point in the stroke.

In treating the above subject, he accuses the present writer of historical mistakes in publishing an abstract of the report in the April number of this *Journal.* To this it is only necessary to reply, that the historical statements were gathered from standard works upon the history of the steam engine, and will naturally stand as true until *proven* incorrect.

In conclusion, I would remark that it is seldom that a report of 38 pages of printed matter, giving the results of an extensive set of experiments upon an important subject, has not some point so weak that it may be successfully assailed; and if the paper to which this is a reply is the heaviest artillery that can be brought against it, the Board have abundant reason for congratulation that they have been so successful.

To Check the Warping of Planks.

The face of the planks should be cut in the direction which lay from east to west as the tree stood. If this be done, the planks will warp much less than in the opposite direction. The strongest side of a piece of timber is that which in its natural position faced the north.—*Dingler's Polytech. Jour. Bull. Soc. d'Encour. pour l'Indus. Nation.*

For the Journal of the Franklin Institute.

Resistance of Wrought Iron Tubes to External and Internal Pressure. Deduced from Experiments of W. Fairbairn.

By Chas. H. Haswell, C. E.

(Continued from page 306.)

No. 2.

Resistance of Wrought Iron Clylindrical Tubes to Internal Pressure.

Taking the mean of the results of Experiments 31 and 34 on iron tubes,

$$P = \frac{P' \times d}{2t}, \text{ or } \frac{425 \times 6}{2 \times .043} = 29{,}651 \text{ lbs.},$$

$$\text{and } \frac{2t \times P}{P'} = d, \text{ or, } \frac{2 \times .043 \times 29{,}651}{425} = 6 \text{ ins.},$$

$$\text{and } \frac{P \times 2t}{d} = P'.$$

Hence, *To ascertain the Thickness of a Wrought Iron riveted Tube or Flue, the Diameter of the tube and the Pressure in pounds per square inch being given.*

Rule.—Multiply the pressure in pounds per square inch, by the diameter of the tube in inches, and divide the product by twice the tensile resistance of the metal in pounds per square inch.

Example.—The diameter of a wrought iron flue is 6 inches, and the pressure to which it is to be submitted is 425 lbs. per square inch, what should be the thickness of the metal?

Assume the tensile strength to be as above, 29,651 *lbs.*

$$\frac{425 \times 6}{29651 \times 2} = \frac{2550}{59302} = .043 \text{ in.}$$

The tenacity or tensile resistance of wrought iron boiler plates, ranges from 62,000 to 42,000 lbs.* per square inch; hence it appears,

* Including English plates.

that in the cases given, are duction of tenacity of about ·4 must be made.

From Experiments 7, 8, 10, and 11, and 31, 32, 33, and 34, it appears that tubes or flues subjected to internal pressure or bursting, have much greater resistance than when subjected to external pressure or collapsing; in the cases given where the lengths of the collapsed tubes were 2·5 feet, the difference is about 6·2 times.

The difference, however, between these strains cannot be determined as a rule, for the reason that the resistance to internal pressure is inversely as the diameter of the tube or flue alone, without regard to its length; whereas, with the resistance to collapse, the stress is inversely as the product of the diameter and the length.

Application to Construction of the Results of the Experiments.

Throughout the experiments here enumerated, it has been proved that the resistance to collapse from a uniform external pressure, in cylindrical tubes or flues, varies in the inverse ratio of the lengths. This law has been tested to lengths not exceeding fifteen diameters of the tube or flue; but the point at which it ceases to hold true is as yet undetermined, and it can only be ascertained by a series of experiments on tubes and flues of greater length, in which the strength of the material modifies the above law of resistance to collapse. Such experiments are desirable, but the results already obtained appear to supply the data necessary for calculating the resistance, and proportioning the material in ordinary cases.

Thus, with drawn or brazed tubes, when there are no courses and consequent laps; their length is an essential element in an estimate of their resistance to collapse; but with riveted flues, constructed in courses, the objection to length is removed, as the addition of the laps is a source of great resistance to collapse, rendering the flue alike to a series of lengths, each equal to the distance between the centres of the courses.

In a boiler of the ordinary construction, of 30 feet in length and 3 feet 6 inches in diameter, with two flues 16 inches in diameter, the cylindrical external shell has 2·8 times resistance to the force tending to burst it, than the flues have to resist the same force to collapse them. This being the case, it is not surprising that the collapse of the internal flues so frequently occurs. To remedy this, and to place the security of boilers upon a more certain basis, it is essential that every part should be of *uniform strength* to resist the stress upon it. The equalization of the powers of resistance is the more important, as the increased strength of the outer shell is absolutely of no value, so long as the internal flues remain liable to be destroyed by collapse, at a pressure of only one-third of that required to burst the envelope which contains them.

The following Table, deduced from experiments, exhibits the collapsing pressure of flues, and bursting pressure of boilers of different diameters and thickness of metal:—

TABLE *of the Resistance of Wrought Iron Flues to an External or Collapsing Pressure, and of the Shells of Boilers to an Internal or Bursting Pressure.*

Tensile resistance of the Plates without riveting is taken at a mean of 55,000 *pounds per square inch.*

FLUES.				SHELLS.			
						Bursting Pressure per square inch.	
Diameter of Flue.	Length of Flue.	Thickness of Flue.	Collapsing Pressure per square inch.	Diameter of Shell.	Thickness of Shell.	Single riveted.	Double riveted.
Ins.	Feet.	Ins.	lbs.	Feet.	Ins.	lbs.	lbs.
6	10	·2	417	2	·25	573	745
6·5	"	·2	385	2·6	·25	458	596
7	"	·2	357	3	·25	382	496
	"	·25	580	3·4	·25	318	414
7·5	"	·2	333		·3125	398	518
	"	·25	542	3·6	·25	327	426
8	"	·2	312		·3125	409	532
	"	·25	508	4	·25	286	372
8·5	"	·2	294		·3125	358	465
	"	·25	478	4·6	·25	254	331
9	"	·2	278		·3125	318	413
	"	·25	451	5	·25	229	298
9·5	"	·2	263		·3125	286	372
	"	·25	427	5·6	·25	208	270
10	12	·2	227		·3125	260	338
	"	·25	354		·375	312	406
	"	·3125	612	6	·25	191	248
10·5	"	·2	216		·3125	239	311
	"	·25	337		·375	286	372
	"	·3125	583	6·6	·3125	220	287
11	"	·2	206		·375	264	344
	"	·25	322	7	·3125	204	266
	"	·3125	557		·375	245	319
11·5	"	·2	197	7·6	·3125	191	248
	"	·25	308		·375	229	298
	"	·3125	532	8	·3125	179	233
12	15	·2	153		·375	215	279
	"	·25	239	8·6	·3125	168	219
	"	·3125	415		·375	202	263
12·5	"	·25	229	9	·3125	159	207
	"	·3125	398		·375	191	248
13	"	·25	220	9·6	·3125	150	196
	"	·3125	384		·375	181	235
13 5	"	·25	212	10	·3125	143	186
	"	·3125	369		·375	172	224
14	18	·25	176		·5	229	298
	"	·3125	305	10·6	·3125	136	177
14·5	"	·25	169		·375	163	212
	"	·3125	294		·5	218	284
15	20	·25	157	11	·375	156	203
	"	·3125	276		.5	208	271
15·5	"	·25	152	11·6	·375	149	194
	"	·3125	267		·5	199	259
16	"	·25	148	12	·375	143	186
	"	·3125	231		·5	191	248

NOTE.—The single riveted are estimated at ·5 the resistance of the plates, and the double riveted at ·65; this reduction from ·56 and ·7, as determined by Fairbairn, is to meet defects of rivets, cracks of plates from the priming of rivet holes, &c., his experiments having been made with rivets and plates in a normal condition.

APPLICATION OF THE PRECEDING TABLE.

To ascertain the Ultimate Collapsing Resistance of a Flue.

When the thickness of the metal is not given in the above Table.

RULE.—Take the square of the thickness of the metal, if given in decimals of an inch, or that due to the number of it, if given by a wire gauge, and multiply it by its proportional unit or multiplier from the table preceding (page 395), the thickness and length being duly considered, and divide the product by the product of the diameter of the flue in inches, and the length of it in feet.

EXAMPLE.—The diameter of a flue is 15 ins., the thickness of the metal No. 3 U. S. wire gauge (= ·23 in.), and the length of it is 30 feet; what is its ultimate resistance to collapse per square inch?

Multipliers for thicknesses from ·125 to ·25 in., and for a length of 30 feet, are 810,000 to 920,000, the difference of which is (920,000 — 810,000) = 110,000, and the difference in thickness (·25 — ·125) = ·125

Then, as ·125 : 110,000 : : ·105 (·23 — ·125) : 92,400.

Difference in length (35 — 25) = 10.

Then, as 10 : 110,000 : : 5 (35 — 30) : 55,000.

Consequently, $\frac{92,400 + 55,000}{2} = 73,700$, a mean multiplier of thicknesses and length, which added to 810,000, the multiplier for ·125 in. in thickness and 25 feet in length, = 883,700.

Hence, $\frac{·23^2}{30 \times 15} \times 883,700 = \frac{·0529}{450} \times 883,700 = 103·88$ *lbs.*

To ascertain the Ultimate Bursting Resistance of the Shell of a Boiler.

When the thickness of the metal is not given in the above table.

RULE.—Double the thickness given, or as ascertained, for a wire gauge, and multiply the sum by the tensile resistance of the metal, and divide the product by the diameter of the flue in inches.

EXAMPLE.—The diameter of the shell of a wrought iron boiler, single riveted, is 5 feet, and the thickness of the metal is ·28 in.; what is the ultimate resistance to a bursting pressure?

$$·28 + ·28 \times 55,000 = 30,800,$$

and $\frac{30,800}{60} = 513·33$ *lbs.*, which × ·5 for reduction of resistance of the plates for single riveting = 256·67 *lbs.*

NOTE.—From the results given in the table and deduced from the

rules, such allowances for the resistance and wear of the plates, oxidation, &c., &c., are to be made, as the character of the metal, the nature of the service, and the circumstance of using fresh or salt water, &c., &c., will render necessary.

In plates single riveted, it is customary in practice to estimate the tensile resistance of the metal at one-fifth of its ultimate resistance, and, when they are double riveted, at one-fourth of it.

Comparison between the Resistance to External and Internal Pressure in Wrought Iron Single Riveted Flues of different Diameters and Lengths.

Diameter.	Thickness.	Length.	External pressure per sq. inch.	Internal pressure per sq. inch.	Ratio.
Ins.	Ins.	Feet.	lbs.	lbs.	
6	·15	10	205	1375	1 to 6·7
12	·2	15	163	917	1 " 5·6
18	·25	20	135	764	1 " 5·6

Resistance of Lead Tubes to Internal Pressure.

Diameter.	Length.	Thickness.	Pressure of rupture per sq. inch.	Remarks.
Ins.	Ins.	Ins.	lbs.	
3	14½	·25	374	Ruptured in body of tube.
3	31	·25	364	

Assuming 370 as the mean of the pressure of rupture in lbs. per square inch,

$$P = \frac{P' \times D}{2t}, \quad \text{or} \quad \frac{370 \times 3}{2 \times \cdot 25} = 2220 \text{ lbs.},$$

$$\text{and} \quad \frac{2t \times P}{P'} = d, \quad \text{or} \quad \frac{2 \times \cdot 25 \times 2220}{370} = 3 \text{ ins.},$$

$$\text{and} \quad \frac{P \times 2t}{d} = P'.$$

Hence, *To ascertain the Thickness of a Lead Pipe, the Diameter and the Pressure in pounds per square inch being given.*

Rule.—Multiply the pressure in pounds per square inch by the diameter of the pipe in inches, and divide the product by twice the tensile resistance of the metal in pounds per square inch.

Example.—The diameter of a lead pipe is 3 inches, and the pressure to which it is to be submitted is 370 lbs. per square inch; what should be the thickness of the metal?

$$\frac{370 \times 3}{2220 \times 2} = \frac{1110}{4440} = \cdot 25 \text{ in.}$$

RESISTANCE OF GLASS GLOBES AND CYLINDERS TO COLLAPSING (Fairbairn).

GLOBES.				CYLINDERS.			
Diameter.	Length.	Thickness.	Collapsing pressure per sq. inch.	Diameters.		Thickness.	Collapsing pressure per sq. inch.
Ins.	Ins.	Ins.	lbs.	Ins.	Ins.	Ins.	lbs.
5·05	4·76	·015	292	4·06	13·75	·045	180
5·08	4·70	·019	410	4·02	14	·065	297
4·95	4·72	·021	470	4·05	7	·046	380
5·60		·020	475	4·05	7	·034	202
8·22	7·45	·010	350	3·09	14	·024	850
8·20	7·30	·012	420	3·08	14	·032	103
8·20	7·40	·015	600	3·25	14	·042	175

From which it appears that the resistance of cylindrical vessels exposed to a uniform external pressure, varies inversely as their lengths.

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillars: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By WM. BRYSON, Civ. Eng.

(Continued from page 330.)

Mr. Hodgkinson gives the following formula for the strength of a solid pillar of cast iron:

$$W = m \times \frac{D^{3.6}}{L^{1.65}},$$

m representing a weight which varied from 49·94 tons in the strongest iron tried, to 33·60 tons in the weakest.

Mr. H. also gives the following formulæ for the strength of a hollow pillar of Low Moor iron, No. 2:

$$W = 46{\cdot}65 \frac{D^{3.55} - d^{3.55}}{L^{1.7}}$$

$$W = 42{\cdot}347 \frac{D^{3.5} - d^{3.5}}{L^{1.63}}.$$

"It was found that when the length was the same, the strength varied as the 3·5 power of the diameter, and when the diameter was the same and the length varied, the strength was inversely as the 1·63 power of the length; both of these were obtained from mean results of many experiments."

NOTE.—The above formulæ are deduced from experiments on pillars 10 feet long, and from 2½ inches to 4 inches diameter.

It was shown at p. 186 of this *Journal*, and by the several tables, that similar formulæ were applicable for solid pillars when the length exceeded 25 diameters, and for hollow pillars when the length varied from about 28 to 34 diameters, the variability depending a good deal upon the sectional thickness.

In the following formulæ by which the tables for cast iron pillars are calculated, the co-efficients for the strength which are not Mr. Hodgkinson's, are all deduced from his experiments. The 41·77 is a mean of the strongest and weakest iron tried, and the 33·60 is the weakest.

Solid Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Name of Iron.	Length or height of Pillar in feet.	Diameter in inches.	Calculated breaking weight in tons from formula, $w = 57{\cdot}17 \frac{D^{3.55}}{L^{1.7}}$.	Calculated breaking weight in tons from formula, $w = 50{\cdot}94 \frac{D^{3.5}}{L^{1.63}}$.	Breaking weight in tons from Mr. Hodgkinson's experiments.
Old Park Iron, Stourbridge,	8	2½	43·11	42·44	
	10	"	29·50	29·50	29·50
	12	"	21·63	21·91	
Derwent Iron, Durham,			$w = 54{\cdot}32 \frac{D^{3.55}}{L^{1.7}}$.	$w = 48{\cdot}40 \frac{D^{3.5}}{L^{1.63}}$.	
	8	2½	40·96	40·32	
	10	"	28·02	28·03	28·03
	12	"	20·56	20·82	
Portland Iron, Tovine, Scotland,			$w = 52{\cdot}90 \frac{D^{3.55}}{L^{1.7}}$.	$w = 47{\cdot}14 \frac{D^{3.5}}{L^{1.63}}$.	
	8	2½	39·89	39·27	
	10	"	27·29	27·30	27·30
	12	"	20 02	20·28	
Calder Iron, Lanarkshire,			$w = 52{\cdot}49 \frac{D^{3.55}}{L^{1.7}}$.	$w = 46{\cdot}77 \frac{D^{3.5}}{L^{1.63}}$.	
	8	2½	39·58	38·96	
	10	"	27·08	27·08	27·09
	12	"	19·86	20·12	
Level Iron, Staffordshire,			$w = 47{\cdot}80 \frac{D^{3.55}}{L^{1.7}}$.	$w = 42{\cdot}59 \frac{D^{3.5}}{L^{1.63}}$.	
	8	2½	36·04	35·48	
	10	"	24·66	24·66	24 67
	12	"	18·09	18·32	
Coltness Iron, Edinburgh, and Carron Iron, Stirlingshire,			$w = 45{\cdot}58 \frac{D^{3.55}}{L^{1.7}}$.	$w = 40{\cdot}61 \frac{D^{3.5}}{L^{1.63}}$.	
	8	2½	34·34	33 83	
	10	"	23·52	23·51	23 52
	12	"	17·25	17·47	
Blaenavon Iron, South Wales,			$w = 42{\cdot}73 \frac{D^{3.55}}{L^{1.7}}$.	$w = 38{\cdot}07 \frac{D^{3.5}}{L^{1.63}}$.	
	8	2½	32·22	31·71	
	10	"	22·05	22·04	22·05
	12	"	16·17	16·37	
Old Hill Iron, Staffordshire,			$w = 38{\cdot}85 \frac{D^{3.55}}{L^{1.7}}$.	$w = 34{\cdot}62 \frac{D^{3.5}}{L^{1.63}}$.	
	8	2½	29·29	28·84	
	10	"	20·04	20·04	20·05
	12	"	14·70	14·89	

Solid Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Diameter in inches.	Calculated breaking weight in tons from formula, $W = 42{\cdot}20\,\frac{D^{3.6}}{L^{1.7}}$.	Calculated breaking weight in tons from formula, $W = 41{\cdot}77\,\frac{D^{3.5}}{L^{1.63}}$.	Calculated breaking weight in tons from formula, $W = 33{\cdot}60\,\frac{D^{3.5}}{L^{1.63}}$.
8	2	14·91	15·93	12·81
9	"	12 21	13·14	10·57
10	"	10·20	11·07	8·90
11	"	8·68	9·48	7·62
12	"	7·48	8·22	6·61
8	$2\frac{1}{16}$	33·31	34·80	30·80
9	"	27·26	28·72	23·11
10	"	22 79	24·19	19·45
11	"	19·38	20·71	16·66
12	"	16·72	17·97	14·45
8	3	64·22	65·88	53·00
9	"	52·56	54·37	43·73
10	"	43·94	45·79	36·83
11	"	37·37	39·21	31·54
12	"	32·23	34·02	27·36
13	"	28·13	29·86	24·02
14	"	24 80	26 46	21·28
15	"	22·05	23·64	19 02
10	4	123·79	125·32	100·81
11	"	105·28	107·31	86·32
12	"	90·80	93·11	74·90
13	"	79 25	81·72	65·74
14	"	69·87	72·42	58·26
15	"	62·13	64·72	52·06
16	"	55·68	58·26	46·86
17	"	50·22	52·75	42·43
18	"	45·57	48·08	38·67
19	"	41·57	44 03	35 42
20	"	38·10	40·49	32·57

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Number of diameters contained in the length or height.	External diameter in inches.	Internal diameter in inches.	Calculated weight of metal contained in pillar in lbs.	Calculated breaking weight in tons from formula, $W = 42{\cdot}347\,\frac{D^{3.5} - d^{3.5}}{L^{1.63}}$.	Value of w.	Value of e.	Calculated breaking weight in tons from formula, $T = \frac{we}{w + \frac{2}{3}e}$.	Breaking weight in tons if irregularly fixed.
8	24	4	2	235·87		166·86	461·58	150·12	50·04
9	27	"	"	265·35		137·53	"	131·23	43·74
10	30	"	"	294·84		115·83	"	115·72	38·57
11	33	"	"	324·28	99·18				33·06
12	36	"	"	353·76	86·05				28·68
13	39	"	"	383·24	75·53				25 17
14	42	"	"	412·72	66·93				22 31

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed (Continued).

Length or height of Pillar in feet.	Number of diameters contained in the length or height.	External diameter in inches.	Internal diameter in inches.	Calculated weight of metal contained in pillar in lbs.	Calculated breaking weight in tons from formula, $w = 42{\cdot}347 \frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{l^{1{\cdot}65}}$.	Value of w.	Value of c.	Calculated breaking weight in tons from formula, $T = \frac{wc}{w + \frac{1}{4}c}$.	Breaking weight in tons if irregularly fixed.
15	45	4	2	442·20	59·81				19·93
16	48	"	"	471·68	53·84				17·94
17	51	"	"	501·16	48 75				16·25
18	54	"	"	530·64	44·44				14·81
19	57	"	"	560·12	40·69				13·56
20	60	"	"	589·60	37·42				12·47
8	19·2	5	3	314·49		332·15	615·75	257·59	85·86
9	21·6	"	"	353·80		274·29	"	229 44	76·48
10	24	"	"	393·12		231·02	"	205·31	68·43
11	26·4	"	"	432·43		197·82	"	184·66	61·55
12	28·8	"	"	471·74		171·63	"	166·83	55·61
13	31·2	"	"	511·05	150·64				50·21
14	33·6	"	"	550·36	133·50				44·50
15	36	"	"	589·68	119 30				39·76
16	38·4	"	"	628·99	107·39				35·79
17	40·8	"	"	668 30	97·24				32·41
18	43 2	"	"	707·61	88·63				29·54
19	45·6	"	"	746·92	81·16				27·05
20	48	"	"	786·24	74·64				24 88
					$w = 46{\cdot}65 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{l^{1{\cdot}7}}$.				
8	17·454	$5\frac{1}{2}$	$3\frac{3}{4}$	317·84		429·54	622·54	298·29	
9	19·636	"	"	357·57		351·60	"	267·42	
10	21·818	"	"	397·30		293 94	"	240·50	
11	23 100	"	"	437 03		249 97	"	217·07	
12	26·181	"	"	476·76		215·60	"	196·65	
13	28·363	"	"	516 49		188·17	"	178·80	
14	30·545	"	"	556·22		165·89	"	163·20	
15	32·727	"	"	595·95	147·54				
16	34·909	"	"	635·68	132·20				
17	37 090	"	"	675·41	119·25				
18	39·272	"	"	715·14	108·22				
19	41·454	"	"	754 87	98·71				
20	43·636	"	"	714·60	90·46				

Solid Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Number of diameters contained in the length or height.	Diameter in inches.	Calculated weight of metal contained in pillar in lbs.	Calculated breaking weight in tons from formula, $w = 42{\cdot}20 \frac{D^{3{\cdot}6}}{l^{1{\cdot}7}}$.	Value of w.	Value of c.	Calculated breaking weight in tons from formula, $T = \frac{wc}{w + \frac{1}{4}c}$.
8	17·454	$5\frac{1}{2}$	594·56		569 33	1164·14	459·48
9	19·636	"	668·88		466·02	"	405·12
10	21·818	"	743·20		389·60	"	359·18

Solid Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed (Continued).

Length or height of Pillar in feet.	Number of diameters contained in the length or height.	Diameter in inches.	Calculated weight of metal contained in pillar in lbs.	Calculated breaking weight in tons from formula, $W = 42{\cdot}20\frac{D^{3{\cdot}6}}{L^{1{\cdot}7}}$.	Value of w.	Value of c.	Calculated breaking weight in tons from formula, $T = \frac{w\,c}{w + \frac{1}{2}c}$.
11	23·100	5½	817·52		331·32	1164·14	320·23
12	26·181	"	891·84	285·76			
13	28·363	"	966·16	249·41			
14	30·545	"	1040·48	219 88			
15	32·727	"	1114·80	195·55			
16	34·909	"	1189·12	175 23			
17	37·090	"	1263·44	158·06			
18	39·272	"	1337·76	143·43			
19	41·454	"	1412·08	130·83			
20	43·636	"	1486·40	119·91			

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Number of diameters contained in the length or height.	External diameter in inches.	Internal diameter in inches.	Calculated weight of metal contained in pillar in lbs.	Calculated breaking weight in tons from formula, $W = 42{\cdot}347\frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}63}}$.	Value of w.	Value of c.	Calculated breaking weight in tons from formula, $T = \frac{w\,c}{w + \frac{1}{2}c}$.
8	16	6	4	393·12		572·83	769·69	383·36
9	18	"	"	442·26		472·71	"	346·52
10	20	"	"	491·40		398·15	"	314·17
11	22	"	"	540·54		340·91	"	285·78
12	24	"	"	589·68		295·79	"	260·77
13	26	"	"	638·82		259·62	"	238·77
14	28	"	"	687·96		230·08	"	219·35
15	30	"	"	737·10		205·59	"	202·13
16	32	"	"	786·24	185·07			
17	34	"	"	835·38	167·58			
18	36	"	"	884·52	152 75			
19	38	"	"	933·66	139 88			
20	40	"	"	982·80	128 64			
21	42	"	"	1031·94	118 80			
22	44	"	"	1081·08	110 13			
23	46	"	"	1130 22	102·43			
24	48	"	"	1179 36	95·56			
25	50	"	"	1228·50	89·41			
26	52	"	"	1277·64	83 87			
27	54	"	"	1326·78	78·87			
28	56	"	"	1375·92	74·33			
29	58	"	"	1425·06	70·20			
30	60	"	"	1474·20	66·42			

Solid Square Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet	Number of diameters contained in the length or height.	Side of the square in inches.	Cubical content in feet.	Approximate weight of pillar in lbs.	Calculated breaking weight in tons from formula, $W = 10{\cdot}95\frac{D^4}{L^2}$.	Value of w.	Value of c.	Calculated breaking weight in tons from formula, $T = \frac{w\,c}{w + \frac{1}{2}c}$.
8	16	6	2·00	94·32		221·73	124·20	87·45
9	18	"	2·25	106·11		175·20	"	81·08
10	20	"	2·50	117·90		141·91	"	74 98
11	22	"	2·75	129·60		117·28	"	69·22
12	24	"	3·00	141·48		98·55	"	63 84
13	26	"	3·25	153 27		83·97	"	58·88
14	28	"	3·50	165·06		72·40	"	54 31
15	30	"	3·75	176·85		63·07	"	50·14
16	32	"	4·00	188 64		55·43	"	46·33
17	34	"	4·25	200·43		49·10	"	42 86
18	36	"	4·50	212·22		43 80	"	39·72
19	38	"	4·75	224 01		39 31	"	36·85
20	40	"	5·00	235·80		35·47	"	34·25
21	42	"	5·25	247·59		32·17	"	31·88
22	44	"	5·50	259 38	29·32			
23	46	"	5·75	271·17	26·82			
24	48	"	6 00	282·96	24·63			
25	50	"	6·25	294·75	22·70			
26	52	"	6·50	306·54	20·99			
27	54	"	6·75	318 33	19 46			
28	56	"	7·00	330·12	18·10			
29	58	"	7·25	341·91	16·87			
30	60	"	7·50	353·70	15·76			

Solid Square Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.

					$W = 7{\cdot}81\frac{D^4}{L^2}$.			
8	16	6	2 00	87·04		158·15	105·84	70 46
9	18	"	2·25	97·92		124 96	"	64·72
10	20	"	2·50	108 80		101·21	"	59 31
11	22	"	2 75	119·68		83·65	"	54·30
12	24	"	3·00	130·56		70·29	"	49 70
13	26	"	3 25	141·44		59·89	"	45 51
14	28	"	3·50	152·32		51·64	"	41·71
15	30	"	3 75	163·20		44·98	"	38·28
16	32	"	4·00	174·08		39·53	"	35·18
17	34	"	4·25	184·96		35 02	"	32 39
18	36	"	4 50	195·84		31·24	"	29·89
19	38	"	4·75	206·72		28·03	"	27·62
20	40	"	5 00	217·60	25·30			
21	42	"	5·25	228·48	22 95			
22	44	"	5·50	239·36	20 91			
23	46	"	5·75	250·24	19·13			
24	48	"	6·00	261·12	17·57			
25	50	"	6·25	272·00	16·19			
26	52	"	6·50	282·88	14·97			
27	54	"	6·75	293·76	13·88			
28	56	"	7·00	304·64	12·91			
29	58	"	7·25	315·52	12·03			
30	60	"	7·50	326·40	11 24			

Solid Cylindrical Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Number of diameters contained in the length or height.	Diameter in inches.	Cubical content in feet.	Approximate weight of pillar in lbs.	Calculated breaking weight in tons from formula, $w = 6{\cdot}71\frac{D^4}{L^2}$.	Value of w.	Value of c.	Calculated breaking weight in tons from formula, $T = \frac{wc}{w+\frac{1}{2}c}$.
8	16	6	1·570	74·08		135·87	97·54	63·40
9	18	"	1·766	83·34		107·36	"	58 01
10	20	"	1·963	92·60		86·96	"	52 97
11	22	"	2·159	101·86		71·86	"	48·33
12	24	"	2·355	111·12		60·39	"	44·10
13	26	"	2 551	120·38		51·45	"	40·27
14	28	"	2·748	129 64		44·36	"	36·82
15	30	"	2 944	138·90		38 64	"	33·71
16	32	"	3·140	148·16		33·96	"	30 92
17	34	"	3·337	157·42		30·09	"	28·42
18	36	"	3·533	166·68		26·84	"	26 18
19	38	"	3·729	175 94	24·08			
20	40	"	3·926	185 20	21·74			
21	42	"	4·122	194·46	19·71			
22	44	"	4·318	203·72	17·96			
23	46	"	4·514	212 98	16·43			
24	48	"	4 711	222·24	15·09			
25	50	"	4·907	231·50	13·91			
26	52	"	5 103	240·76	12·86			
27	54	"	5·300	250·02	11·92			
28	56	"	5·496	259·28	11·09			
29	58	"	5·692	268·54	10·34			
30	60	"	5·889	277·80	9·66			

Solid Cylindrical Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.

					$w = 4{\cdot}79\frac{D^4}{L^2}$.			
8	16	6	1·570	68·40		96·99	83·12	50·59
9	18	"	1·766	76·95		76·64	"	45·83
10	20	"	1·963	85·50		62·07	"	41·46
11	22	"	2·159	94 05		51·30	"	37·52
12	24	"	2·355	102·60		43·11	"	33·98
13	26	"	2·551	111·15		36·73	"	30 81
14	28	"	2·748	119·70		31·67	"	28·00
15	30	"	2·944	128·25		27·59	"	25·50
16	32	"	3·140	136·80		24·24	"	23·27
17	34	"	3·337	145·35		21·48	"	21·30
18	36	"	3·533	153·90	19·16			
19	38	"	3·729	162·45	17·19			
20	40	"	3·926	171·00	15·51			
21	42	"	4·122	179·55	14·07			
22	44	"	4·318	188·10	12·82			
23	46	"	4·514	196·65	11·73			
24	48	"	4·711	205·20	10·77			
25	50	"	4·907	213·75	9·93			
26	52	"	5·103	222·30	9 18			
27	54	"	5·300	230·85	8·51			
28	56	"	5·496	239·40	7·91			
29	58	"	5·692	247·95	7·38			
30	60	"	5·889	256·50	6·89			

Solid Square Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Number of diameters contained in the length or height.	Side of the square in inches.	Cubical content in feet.	Approximate weight of pillar in lbs.	Calculated breaking weight in tons from formula, $W = 10{\cdot}95\frac{D^4}{L^2}$.	Value of w.	Value of c.	Calculated breaking weight in tons from formula, $Y = \frac{wc}{w+\frac{1}{2}c}$.	Breaking weight in tons if irregularly fixed.
8	13 5-7	7	2·72	128·40		410·79	169·05	129·18	43·06
9	15 3-7	"	3 06	144·45		324·57	"	121·56	40·52
10	17 1-7	"	3·40	160·50		262·90	"	114·05	38·01
11	18 6-7	"	3·74	176·55		217·28	"	106·75	35·58
12	20 4-7	"	4·08	192·60		182·57	"	99·76	33·25
13	22 2-7	"	4·42	208·65		155·56	"	93·14	31·04
14	24	"	4·76	224·70		134·13	"	86 90	28·96
15	25 5-7	"	5·10	240·75		116·84	"	81·07	27·02
16	27 3-7	"	5·44	256·80		102·69	"	75·65	25·21
17	29 1-7	"	5·78	272·85		90·97	"	70·62	23·54
18	30 6-7	"	6·12	288·90		81·14	"	65·97	21·99
19	32 4-7	"	6·46	304·95		72·82	"	61·67	20·55
20	34 2-7	"	6·80	321·00		65·72	"	57·71	19·23
21	36	"	7·14	337·05		59·61	"	54·06	18·02
22	37 6-7	"	7·48	353·10		54·32	"	50·70	16·90
23	39 3-7	"	7·82	369·15		49·69	"	47·60	15·86
24	41 1-7	"	8·16	385·20		45·64	"	44·74	14·91
25	42 6-7	"	8·50	401·25	42·06				14·02
26	44 4-7	"	8 84	417·30	38·89				12·96
27	46 2-7	"	9·18	433·35	36·06				12 02
28	48	"	9·52	449·40	33·53				11·17
29	49 5-7	"	9·86	465·45	31·26				10·42
30	51 3-7	"	10·20	481·50	29·21				9·73

Solid Square Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.

					$W = 7{\cdot}81\frac{D^4}{L^2}$.				
8	13 5-7	7	2·72	118·48		292·99	144·06	105·24	35·08
9	15 3-7	"	3·06	133·29		231·50	"	98·22	32·74
10	17 1-7	"	3·40	148·10		187·51	"	91·39	30·46
11	18 6-7	"	3·74	162·91		154·97	"	84·88	28·29
12	20 4-7	"	4·08	177·72		130·22	"	78·73	26·24
13	22 2-7	"	4·42	192·53		110·95	"	72·98	24·32
14	24	"	4·76	207·34		95·67	"	67·65	22·55
15	25 5-7	"	5·10	222·15		83·34	"	62·73	20·91
16	27 3-7	"	5·44	236·96		73·24	"	58·20	19·40
17	29 1-7	"	5·78	251·77		64·88	"	54·05	18·01
18	30 6-7	"	6·12	266·58		57·87	"	50·24	16·74
19	32 4-7	"	6·46	281·39		51·94	"	46·77	15·59
20	34 2-7	"	6·80	296·20		46·87	"	43·58	14·52
21	36	"	7·14	311·01		42·52	"	40·68	13·56
22	37 6-7	"	7·48	325·82		38·74	"	38·02	12·67
23	39 3-7	"	7·82	340·63	35·44				11·81
24	41 1-7	"	8 16	355·44	32·55				10·85
25	42 6-7	"	8·50	370·25	30·00				10·00
26	44 4-7	"	8·84	385·06	27·73				9·24
27	46 2-7	"	9·18	399·87	25·72				8·57
28	48	"	9·52	414·68	23·91				7·97
29	49 5-7	"	9·86	429·49	22·35				7·45
30	51 3-7	"	10·20	444·30	20·83				6·94

(To be Continued.)

Fastening of Iron Bars into Stone.

For this purpose, lead is almost always employed, which forms a voltaic couple with the iron, by which that metal is rapidly rusted. Zinc, on the contrary, would preserve the iron.—*Dingler's Polytech. Jour. Bull. Soc. d'Encour. pour l'Indus. Nationale.*

Artesian Well at Passy.

At length the artesian well at Passy (Paris) which has cost so much labor, expense, and anxiety, has met with a successful issue. At a depth of 587 metres (1925·77 ft.), the stratum of water was reached which rises 230 ft. above the level of the Seine, at a temperature of 82·5° Fahr. The water is very pure, and carries with it much less sand than that of Grenelle. The quantity discharged is 25,000 cubic metres (32,695 cub. yds.) in 24 hours.—*Cosmos.*

The Working Power of Coal.

From the Lond. Mechanics' Mag., September, 1861.

Professor Rogers estimates that nearly one-sixth of the total annual produce of our coal mines is used for the production of mechanical power alone, from which a power equal to that of 66,000,000 able bodied men is obtained. Each acre of a seam yielding three feet of pure fuel, is equal to about 5000 tons, and possesses a reserve of mechanical strength equal to the labor of 1600 men during their whole life; and each square mile of the same bed contains 8,000,000 tons of fuel, which is equal to 1,000,000 men laboring through twenty years of their ripe strength. Upon the same calculation, the total annual coal production of the United Kingdom (65,000,000 tons) is equal to the strength of 400,000,000 strong men, or more than double the number of adult males now upon the globe.

For the Journal of the Franklin Institute.

On Feed Pump Resistance. By Wm. H. Shock, Ch. Eng. U. S. N.

In the January number of this *Journal* for the present year, will be found a series of diagrams taken from the feed pumps of the U.S. steam frigate *Powhatan* (paddle wheel), with the data and results deduced therefrom.

Since that time, I have been kindly furnished by Chief Engineer Thos. A. Shock, of the U. S. steam sloop *Mohican* (screw), with a series of diagrams taken from the cylinders and feed pumps of that ship, which enables me to continue the investigation of "Feed Pump Resistance."

The steam sloop *Mohican* is one of six sloops built in 1858–9, and since her completion has been actively engaged on the coast of Africa.

Her general dimensions are as follows:—

Length, extreme,	232 feet.
" at load line,	188 " 6 ins.
Breadth of beam,	33 "
Tonnage,	1330.

She is supplied with two horizontal direct-acting double piston rod engines, of the following dimensions:—

Diameter of cylinders,	54 inches.
Stroke of piston,	30 "
Diameter of fresh-water air-pump,	15 "
" salt " "	21 "
" feed pump,	4 "
Internal diameter of feed pipes,	3½ "

One screw, composition, with an increasing pitch.

Diameter,	12 ft. 6 ins.
Length,	2 " 9 "
Pitch,	from 17 to 21 "

Diagrams A and B, and Nos. 1, 2, and 3, were taken as near the same period of time as was practicable, to avoid as far as possible any error that might arise from a change in the working condition of the engines. The data, therefore, as to revolutions, &c., &c., affixed to diagrams A and B is critically correct for Nos. 1, 2, and 3. As our object is to ascertain what per centum of the developed H. P. of the engines was absorbed in overcoming the resistance of feed pumps, it becomes necessary as a preliminary step to ascertain what this power was, and for this purpose we have recourse to diagrams A and B, from which we find the following:—

Mean effective pressure from card A = 6·9 lbs.
" " " B = 8·3 "

and $\frac{6{\cdot}9+8{\cdot}3}{2} = 7{\cdot}6$ lbs., as the mean average effective pressure acting on the pistons.

Therefore, $\frac{2290\times7{\cdot}6\times42{\cdot}4\times10}{33{,}000} = 223{\cdot}6+\text{H. P.}$,*

the total effect developed by the engines, when the accompanying series of diagrams were taken.

Having ascertained that the exponent of labor performed by the engines is represented by 223·6 + H. P., it remains to be seen what proportion of it was absorbed by the pumps.

The area of the steam piston, as we have seen, is 2290·2 sq. ins.
Area of pump plunger, . . 12·556 "

and $\left(\frac{12{\cdot}556}{2290{\cdot}2}\right)\cdot5 = {\cdot}0027434 =$ the proportion of area of feed pump to double that of the steam cylinder.

From diagrams Nos. 1, 2, and 3, we ascertain the resistance per square inch of pistons under the three several conditions in which they were taken, as follows:—

* About one-half the usual working power of the engines.

CARD No. 1.—The mean pressure . . = 6·07 lbs.

and $6{\cdot}07 \times {\cdot}0027434 = {\cdot}016652438$

= the resistance per sq. in. of pistons; or, in terms of H. P., we have

$$\frac{12{\cdot}566 \times 6{\cdot}07 \times 42{\cdot}4 \times 2{\cdot}5}{33{,}000} = {\cdot}245 \text{ H. P.}$$

CARD No. 2.—The mean pressure . . = 3·8 lbs.

and $3{\cdot}8 \times {\cdot}0027434 = {\cdot}01042492$

= the resistance per sq. in. of pistons; or, in terms of H. P., we have

$$\frac{12{\cdot}566 \times 3{\cdot}8 \times 42{\cdot}4 \times 2{\cdot}5}{33{,}000} = {\cdot}153 \text{ H. P.}$$

CARD No. 3.—The mean pressure . . = 5·5 lbs.

and $5{\cdot}5 \times {\cdot}0027434 = {\cdot}0150887$

= the resistance per sq. in. of pistons; or, as in the other two cases, we have

$$\frac{12{\cdot}566 \times 5{\cdot}5 \times 42{\cdot}4 \times 2{\cdot}5}{33{,}000} = {\cdot}221 \text{ H. P.}$$

By reference to the plate of diagrams, it will be seen that No. 1 represents the power absorbed by *one* pump (in its normal working condition for that speed) to be ·245 H. P., and $·245 \times 2 = ·490$ H. P., which represents the total tax on the engines for feed pump resistance "*per se*," as shown by the diagrams, the friction resistance due to packing, &c., not being considered.

It will of course be understood that pump resistance increases with increase of boiler duty, and in addition to the usual tortuous and irregular manner in which feed pipes are generally arranged on board ship (which of itself is a fruitful source of resistance), may be mentioned the confined space in check valve chambers.

In the designs of feed pumps, check valve chambers, &c., particular attention should be given, especially in quick working engines. I know of a case in which a violent jar in the working of feed pumps was removed by the engineer simply enlarging the check valve chambers on boilers half inch, which resulted in the further advantage of not requiring the pump to be so tightly packed as previously, thus avoiding much friction.

—

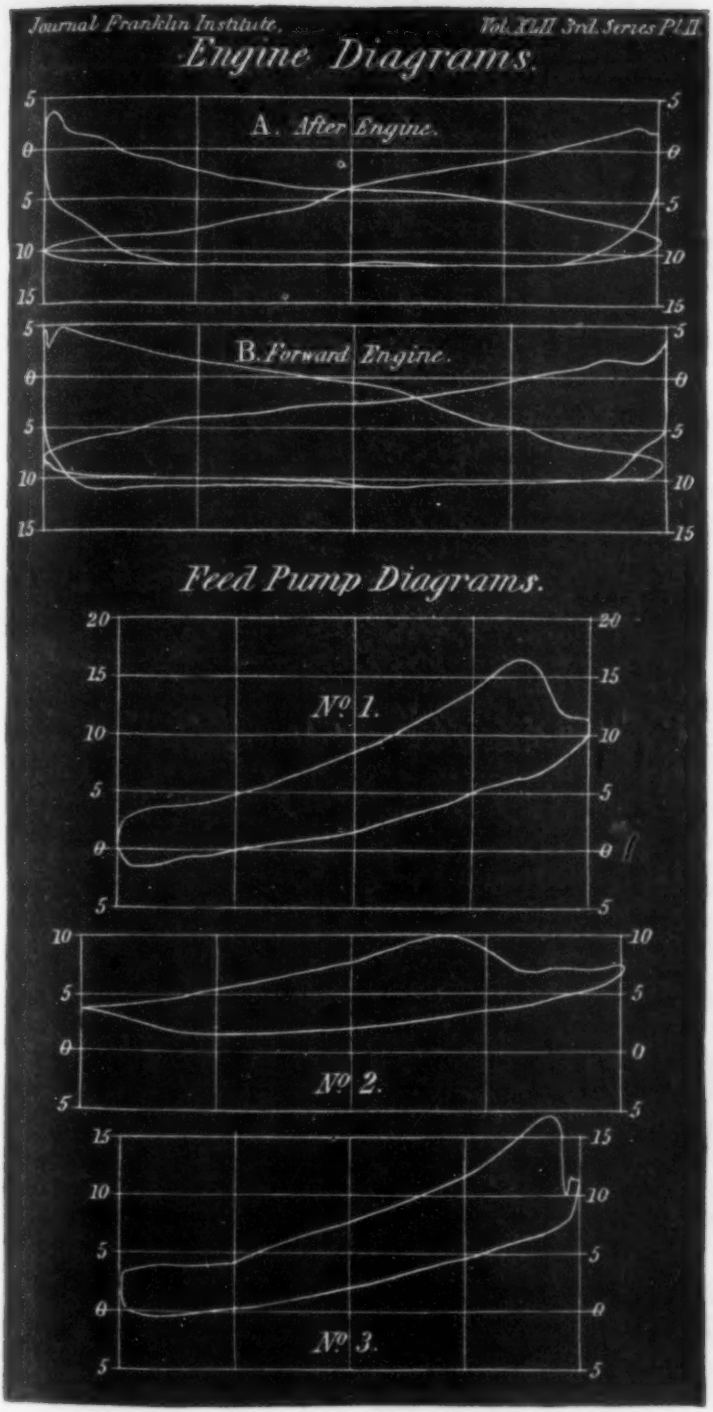
EXPLANATION OF DIAGRAMS.—PLATE II.

ENGINE DIAGRAMS A and B.

Steam, 8½ lbs. Vacuum, 26 inches. Cut-off, 10 inches.
Throttle, 1¼ holes open. Hot-well, 123°.
Revolutions, 43·4 per minute.

FEED PUMP DIAGRAMS.

No. 1.—Feed pump, valves, &c., in their normal working condition.
No. 2.—Feed pump, safety and supply valves wide open, check valves on boiler closed.
No. 3.—Supply valve on pump, and check valve on boiler, wide open.


Engine Diagrams.
A. After Engine.
B. Forward Engine.
Feed Pump Diagrams.
No 1.
No 2.
No 3.

On the Preparation of Artificial Coloring Matters with the Products Extracted from Coal Tar. By M. E. Kopp.

From the Lond. Chemical News, Nos. 51 and 52.

(Continued from page 339.)

There is a second aniline compound, in which two equivalents of hydrogen are replaced by two equivalents of nitrous acid, dinitraniline $= C_{12}H_5\,2(NO_4)N$. By the prolonged action of sulphuretted hydrogen and ammonia on nitraniline and dinitraniline two new bases are produced,—and *azophenylamine* and *nitrazophenylamine*. The following equations express the reactions which take place :—

$$\underset{\text{Nitraniline.}}{C_{12}H_6N_2O_4} + 6HS = \underset{\text{Azophenylamine.}}{C_{12}H_8N_2} + 4HO + 6S.$$

$$\underset{\text{Dinitraniline.}}{C_{12}H_5N_3O8} + 6HS = \underset{\text{Nitrazophenylamine.}}{C_{12}H_7N_3O_4} + 4HO + 6S.$$

The second of these bases, nitrazophenylamine, merits some attention, inasmuch as it offers some resemblance to the colored derivatives of aniline. It is prepared in the following manner :* Dinitraniline is boiled for two hours with a great excess of sulphide of ammonium. The liquid soon becomes dark red ; the yellow crystals of dinitraniline disappear, and are succeeded by a network of delicate needles, of a deep red color, the quantity of which is much increased on cooling the liquid after the reaction has terminated. Oxalic and hydrochloric acids dissolve the nitrazophenylamine, leaving the precipitated sulphur, and also a secondary crystallized product of a dirty green color. The base may be obtained pure by precipitating a boiling oxalic or hydrochloric solution with ammonia and re-crystallizing two or three times from a solution in hot alcohol. In this way nitrazophenylamine is obtained in long slender needles, united in groups, having a clear red color when dry, and showing a golden iridescence. Water, alcohol, and ether easily dissolve it, and the concentrated solutions are of a deep red color. It melts at a high temperature, and the greater part is volatilized apparently without alteration. Heated suddenly, it slightly explodes, leaving a carbonaceous residue.

The salts of nitrazophenylamine are very beautiful compounds, characterized by a dichroism which causes a peculiar iridescence in reflected light. All the salts must be crystallized in the presence of an excess of acid, since both water and alcohol decompose the neutral salts.

Fuchsine prepared by chloride of tin, according to the process of MM. Renard and Franc, appears to be the hydrochlorate of a base, the properties of which greatly resemble those of nitrazophenylamine. The crystallized salts show the same colored reflections, and are decomposed (in part at least) by water and alcohol, the solutions being of a deep red color.

We now proceed to notice the processes for the preparation of coloring matters by means of aniline, and the method of employing them for dyeing fabrics and yarns.

* Gerhardt, *Chimie Organ.*, iii. p. 105; Gmelin's "Handbook," xi. p. 294.

The first on the list is that of Mr. Perkin, for the preparation of aniline, violet, or mauve. A cold solution of sulphate of aniline (rough aniline is used) and a cold solution of bichromate of potash are mixed together and left for ten or twelve hours. An abundant deposit of a black powder is thus obtained, which is separated, well washed with water, and, lastly, dried at 212°. The dried substance is then digested several times with naphtha or commercial benzole, which dissolves a brown tarry or resinous substance, contaminating the coloring matter in the deposit. The residue insoluble in the naphtha is dried again, and then digested with wood spirit or alcohol, or any other liquid able to dissolve the coloring matter. This clear solution is decanted and distilled to recover the solvent. The residue of the distillation is anileine, or aniline violet.

Mr. Perkin gives the following directions for dyeing with anileine: To dye a lilac or purple, an alcoholic solution of the coloring matter is added to a boiling dilute solution of oxalic and tartaric acids, and when the mixture has cooled the materials to be dyed (silk, cotton, &c.) are to be completely immersed in the bath. Mr. Perkin's patent is dated August 26, 1856. In the early part of 1859, M. Verguin, a chemist at Lyons, while experimenting with aniline, discovered a process for converting it into a magnificent purple-red coloring matter. M. Verguin sold his process to MM. Renard and Franc, who patented the process in France on the 8th of April, 1859, and gave the new coloring matter the name of Fuchsine. The process is as follows:— A mixture of ten parts of aniline with six or seven of anhydrous chloride of tin is boiled for fifteen or twenty minutes. The mixture at first turns yellow, then becomes reddish, and ends by assuming a beautiful red color when seen in thin layers; in the mass it appears black. Water is now added, and the whole is heated to ebullition. It is then removed from the fire, allowed to rest a moment for some insoluble matters to deposit, and then filtered while still hot; the residue is exhausted by another boiling with water. The filtered liquor contains the coloring matter in solution. To separate it, advantage is taken of its being insoluble in a saline solution; accordingly, chloride of sodium or a neutral tartrate of potash or soda, in a solid state, is added to the liquor, and as the salt dissolves the coloring matter is deposited. It may then be separated by decantation or filtration.

Fuchsine may be employed for dyeing either in aqueous solution, without a mordant, or with the ordinary saline or acid mordants, always excepting the mineral acids, which alter the color.

A red color is also obtained by acting on aniline with other anhydrous metallic chlorides, bichloride of mercury, perchloride of iron, protochloride of copper, for example. In October, 1859, MM. Renard and Franc added to the above three anhydrous chlorides the hydrate of bichloride of tin, as being equally able to change aniline into fuchsine. A second addition to their patent, in November, 1859, extended the list of colorigenous agents by including the stannous and stannic sulphates, the mercurous and mercuric sulphates, mercurous and mercuric nitrates, nitrate of silver, titanic chloride, mercuric fluoride,

stannic and mercuric bromides, and stannic iodide. A third addition, in the same month, added the ferric and uranic nitrates, uranic chloride, and mercuric chlorate, bromate, and iodate. Sesquichloride of carbon and iodoform were afterwards added in December of the same year. Lastly, a fifth addition was made in February, 1860, the purport of which the author does not exactly know, but which, he believes, includes iodine, arsenic acid, and nitric acid.

We must here quote from a paper by Dr. Hofmann, presented to the Academy of Sciences, on September 20th, 1858,* and entitled, "Contributions to the History of the Organic Bases: IV. Action of Bichloride of Carbon on Aniline":*—

"At the ordinary temperature of the air, aniline and bichloride of carbon do not act on each other. At 100° C. the mixture begins to change; but after digesting for some days, the change is far from being complete. By submitting, however, a mixture of one part of bichloride of carbon and three parts of aniline, the two bodies being in the anhydrous state, to a temperature of 170° or 180° (the boiling point of aniline), for nearly thirty hours, the liquid is changed into a blackish mass, soft and viscous, or hard and brittle, according to the duration of the temperature. This blackish mass is a mixture of several bodies. By exhausting with water a part is dissolved, another part remaining insoluble in a resinous state. With the aqueous solution, potash gives an oily precipitate, which contains a considerable proportion of unchanged aniline. On distilling this oily matter with diluted potash, aniline passes; while a viscous oil, which solidifies by degrees, remains behind. Repeated washings with cold alcohol, and one or two crystallizations from boiling alcohol, render the body perfectly white and pure; a very soluble substance, of a *magnificent crimson color* remaining in solution.

"The blackish portion of the mass, which remains insoluble in water, is easily dissolved by hydrochloric acid; from this solution, it is again precipitated by alkalies, as a dirty-red amorphous powder, soluble in alcohol, and forming a *rich crimson colored solution*. The greater part of this coloring matter is the same as that which accompanies the crystalline fatty body, considerable quantities of this latter substance being sometimes found in the product insoluble in water."

The great resemblance between the experiments of Dr. Hofmann and the process of MM. Renard and Franc is evident. If, as appears from the fourth addition to their patent, fuchsine may be prepared by boiling sesquichloride of carbon with aniline, it is quite clear that Dr. Hofmann had fuchsine in his hand, and that it is identical with the substance which gave a magnificent crimson solution. It is right, however, to add, that if Dr. Hofmann was the first who obtained fuchsine as a secondary product in his theoretical experiments, M. Verguin has certainly the merit of having modified the process, so as to make it capable of industrial application.

* Comptes-Rendus, t. xlvii. p. 492.

In October, 1859, M. Gerber-Keller patented in France the preparation of a red coloring matter, which he called Azaleine, "by means of aniline treated under the influence of heat and in proper proportions with several salts which are formed by the oxyacids of nitrogen, sulphur, chlorine, bromine, and iodine with metallic oxides." We shall complete this too concise and consequently obscure description of the process by adding what is known respecting the preparation. The salts preferred by the author are the mercurous and mercuric nitrates. Aniline is carefully heated to about 150° C., and nitrate of mercury in powder is then dropped in, a small quantity at a time. A higher temperature than 150° must be avoided, or the action becomes too violent, and the coloring matter is destroyed. At every addition of the mercury salt a sort of ebullition is produced, the consequence of the reaction which takes place; metallic mercury is deposited at the bottom of the vessel, and the liquor gradually acquires a deep crimson color. After being decanted, the whole is allowed to cool, and the coloring matter is now washed with a little water and dried. It is then freed from tarry matters by repeated washings with commercial benzine, and finally dissolved in alcohol or wood spirit, the solution being re-precipitated with water, &c., again and again, until the product is sufficiently pure. Absolute purity is not necessary for either dyeing or printing.

Azaleine is soluble in water, but much less so than in alcohol. For dyeing silk and wool, alcoholic solutions are preferred; for printing on cotton, a dilute alcoholic is thickened with gum.

We have recently heard that the process now employed by M. Gerber-Keller is the following: 10 parts of aniline are heated on a water bath to 100°, and 7 parts of mercuric nitrate, dry and in powder, are added by degrees. The mixture is maintained at the temperature of 100° for eight or nine hours, in which time the mass will have become of a magnificent violet-red color. On cooling it forms a thick paste. The greater part of the reduced mercury is found at the bottom of the vessel. To employ the azaleine then produced as a dye or for printing, it is only necessary to treat the pasty mass with boiling water, a mixture of water and alcohol, acetic acid, or any other solvent, and make use of the solution.

The advantage of the last process consists in the moderate heat required, a high temperature seeming to cause the formation of tarry matters.

M. Albert Schlumberger has also described (*Bulletin de la Société Industrielle de Mulhouse*, March, 1860, p. 170) a process for converting aniline into a red coloring matter by means of the neutral nitrate of mercury. He takes 100 parts of anhydrous aniline, and 60 parts of the nitrate of mercury, and heats the mixture to boiling. The mass slowly changes color, at first becoming brown, but in time the whole is transformed into a beautiful red liquid. The operation is finished when the boiling materials are observed to swell up and disengage yellowish vapors. The mass so obtained is washed with two or three times its volume of boiling water, to remove the oils which

are not completely metamorphosed, and then boiled two or three times with water to extract the coloring matter.

In this process, as well as in the preceding, the whole of the mercury is recovered.

In May, 1860, MM. Girard and Delaire obtained a patent for the use of arsenic acid in the preparation of a red coloring matter from aniline. They introduce into a distillatory apparatus 12 parts of dry arsenic acid, and 12 parts of water. When the hydration of the arsenic acid is complete, they add 10 parts of aniline, and shake the whole well together. The mass becomes homogeneous, pasty, and almost solid. A gentle heat is then applied, so as to raise the temperature of the mixture gradually. The mass now becomes liquid. When the operation is properly conducted, only water and a very small quantity of aniline distil. At 120°, a great part of the aniline is changed into the coloring matter, and care must be taken to keep the mixture at this temperature for some time. The heat may then be increased, but it must never pass 160°. The operation lasts four or five hours.

In the above way a perfectly homogeneous mass is obtained, which is fluid above 100°. On cooling, it solidifies, and has the appearance of a hard, brittle substance, with a bronze lustre. It is very soluble in water, to which it communicates a pure red color, so deep that concentrated boiling solutions appear black. The solutions may be used for dyeing directly without fear, for the tissues will not retain a trace of the arsenic. If necessary, the arsenic may be easily removed from the coloring matter by one of the following processes:—

1. Powder the rough product, and treat it with strong hydrochloric acid; then dilute with water, and saturate the clear solution with a slight excess of soda. The coloring matter is precipitated, while the arsenic remains in solution in the alkali, and it is only necessary to wash the precipitate once or twice with cold water to obtain the coloring matter quite pure.

2. The rough product dissolved in water is treated with a quantity of quick-lime corresponding to the arsenical compounds it contains, *plus* a slight excess. The coloring matter is precipitated, as well as the arsenical compounds,—the latter in the form of insoluble calcareous salts. The liquor and the precipitate (unseparated) are now treated with carbonic, acetic, or tartaric acid, either of which will dissolve the coloring matter and leave the arsenic.

In this process, aniline gives about its own weight of coloring matter.

The process of MM. Depouilly and Lauth, "for the manufacture of various colored products derived from aniline," is very similar to that of Mr. Perkin. They take a solution of a salt of aniline and treat it with a solution of chloride of lime. The first drops of the chloride produce a violet coloration, and, on continuing the addition of the re-agent, a deep violet precipitate is formed, which constitutes the coloring matter. This is collected and washed with slightly acidulated water. When the washings are uncolored, the precipitate is collected

on a filter, and drained. It is then dissolved in a strong acid—sulphuric for example—and re-precipitated by the addition of a large quantity of water, or by an alkaline solution. The product is thus obtained sufficiently pure for sale. For dyeing and printing, alcoholic acid or aqueous solutions may be used, according to the nature of the article to be dyed and the purity of the color required.

The next patents referred to by the author are those of Messrs. Beale and Kirkham, Mr. Kay, Mr. Price, and Mr. G. C. Williams, which have been already described in the *Chemical News* (vol. i., pp. 9, 74, 81).

Electricity by Condensation of Vapor.

Prof. Palmieri records the following experiment: "I gently boiled water in an uninsulated capsule of platina, and condensed the vapors on a platina refrigerator, placed about two feet above the surface of the water; by a condensing electrometer, I detected positive electricity. Encouraged by this favorable result, I insulated the capsule upon the lower plate of a condensing electrometer, and concentrated the rays of the sun upon it by means of a lens of about a foot in diameter. I thus obtained a superficial ebullition scarcely visible, and signs of negative electricity in the capsule."—*Archives des Sciences Physiques et Naturelles*, August, 1860, p. 352.

Dissolving Platina in "Aqua Regia."

In operating on a large quantity of platina, a long time is required, during which the operator is exposed to the acid fumes; and frequently a loss of from 1 to 6 per cent. is experienced, owing to the formation of an insoluble chloride. Doctor Dullo finds that both these inconveniences may be avoided by boiling under a slightly increased pressure, which he obtained by passing through the cover of the mattrass a bent glass tube, the vertical branch of which contains a column of about 3 feet of water. The platina dissolved rapidly and left no residue.—*Jour. für Prak. Chem. Bull. Soc. d'Encour. pour l'Indus. Nationale.*

Colorless Caoutchouc Varnish.

Dr. Bolley recommends to cut the caoutchouc into small strips, and digest them in benzine, at the ordinary temperature; stirring or shaking the mixture frequently and long. The jelly which forms partly dissolves, and gives a liquid heavier than benzine, which may be made nearly colorless by filtration and repose. By pressing the residuum in a strong cloth, may be obtained a dark colored insoluble jelly, which makes a good adhesive covering. It incorporates well with all the fat and volatile oils, and dries rapidly: the surface is not shining. It is very flexible, and may be spread in thin coats.—*Dingler's Polytech. Jour. Bull. Soc. d'Encour. pour l'Indus. Nat.*

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, November 21, 1861.

John C. Cresson, President, in the chair.

John Agnew, Vice President,
John F. Frazer, Treasurer,
Isaac B. Garrigues, Recording Secretary, } Present.

The minutes of the last meeting were read and approved.

Donations to the Library were presented by the Royal Society and the Society of Arts, London; the Oesterreichischen Ingenieur-Vereines, Vienna, Austria; A. Dallas Bache, LL. D., U. S. Coast Survey; Lieut. J. M. Gillis, U. S. Navy; Commissioner of Patents, Washington, D. C.; the Board of Water Commissioners of Jersey City, N. J., and Prof. John F. Frazer, Philadelphia.

Donations to the Cabinet of Minerals—from William T. Harris, Esq., Lancaster County, Penna.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer read his statement of the receipts and payments for the month of October.

The Board of Managers and Standing Committees reported their minutes.

Thirty-six resignations of membership in the Institute were read and accepted.

Candidates for membership in the Institute (13) were proposed, and the candidates proposed at the last meeting (9) were duly elected.

Mr. Howson, of the Committee on Meetings, exhibited the following articles:

1. A Cook Stove for army purposes, the invention of Mr. Isaac S. Williams, of this city. The stove is of sheet iron, of an oblong shape, and has an inner lining, which, when removed and inverted over the top of the stove, forms an oven. In this casing can be packed over eighty utensils to be used for culinary purposes, also a complete set of table articles for a dozen men. Mr. W. has taken steps to procure a patent.

2. An ordinary Springfield Musket, rifled and altered to a breech-loader according to a plan invented by B. F. Joslyn, Esq., of Stonington, Conn. The movable breech tilts over laterally to allow for the insertion of the cartridge, and when depressed to its proper position forms, as it were, part of the barrel. This fire-arm, which has been patented in this country and throughout Europe, has been subjected to severe tests at the Washington Navy Yard, and has been highly recommended, owing to its simplicity, cheapness, and cleanliness.

3. A Military Hat, (invented and patented by E. L. Pascall, Esq., of this city,) which may be readily converted into a dress hat, fatigue cap, or havelock. It has met with the approval of military men, and has been adopted to a considerable extent in the army.

4. A package of Paper Bags, made by a machine invented and patented by Mr. H. G. Armstrong, of this city. Mr. Howson briefly

explained the main features of the machine, and stated that he considered it one of the most ingenious, simple, and effective inventions ever carried out in this city. No less than 800 complete bags can be made by this machine in one minute.

5. A fastening for Shoulder Straps, invented by B. G. Barney, Esq., of this city. It enables the wearer to readily detach the strap from and re-attach it to the shoulder of his coat. Mr. B. has applied for a patent.

6. A model of a combined Floating Battery and Battering Ram, the invention of J. R. Savage, Esq., of Camden, N. J. All the exposed parts of the battery are iron-plated, and so formed as to present an angle of 30 degrees to a shot striking in a horizontal direction. A movable rod or bar can be projected from below the hull, to penetrate the bed of the river or harbor, for the double purpose of anchoring the vessel and serving as a centre, around which it may be revolved by the aid of the rudder and propeller—the guns being thus directed to any desired point.

7. A very simple and ingenious Clasp for Shades of Coal Oil Lamps, the invention of Mr. C. Reichman, of this city.

8. A specimen of a Cravat, for which a design patent had been obtained by Mr. J. A. Eshleman. Mr. Howson stated that he exhibited this specimen with the view of showing the meeting what a number of articles of manufacture could be protected by the new act, which related to patents for designs, a subject as yet not generally understood.

A. C. Jones, Esq., presented an improved Coupling for attaching branch-pipes of fire engines to the nozzle, and also explained his improvements in Floating Batteries.

Henry Pickel, Esq., C. E., of this city, presented an improved Plane Table (for interior work) for Surveyors, consisting of a drawing-board supported on a tripod (theodolite pattern) with a sight ruler. This instrument supersedes the use of the prismatic compass, with field-book. No field-book is required with this instrument.

Also, a Comb Scale Calculator, for calculating the areas of cross-sections of cuttings, embankments, and interior work, with off-sets. With this instrument, Comb Scale Calculator, and a problem in Euclid, calculations of areas ordinarily requiring several hours, could be made in a few minutes, thus doing away with the use of any of the Mathematical Tables. Plans and surveys can be made complete, together with their areas, without the aid of a field-book, as stated.

Mr. A. L. Fleury, chemist and electrician, read the following papers:—

Can light, heat, and motion, successfully and economically be produced by electricity?

This is a very important question, and it is for our present fast-progressing century to answer it by practical demonstrations. Electricity acts the most important part in the mineral, vegetable, and animal economy:—it has been proved to be identical with the vivid and withering lightning, the streaming aurora borealis, the rapid whirlwind, the terrific waterspout, and may probably be the cause of

the falling meteor, and the devastating earthquake; it seems to be the connecting link between mind and matter—figuratively speaking, electricity is the soul of nature.

Already the successful experiments of Prof. Faraday, showing the advantages of the electric light for lighthouses, as also the brilliant trials lately made in Paris, give evidence that our neighbors over the water are on the *qui vive* in this most important subject: the production of light by electricity.

Not only this subject, but also that of heat has been taken into consideration. As proof, I present here an article published recently in the London *Times:*—

"A Trappist, named Delalot-Sevin, of the Abbeye de la Grace-Dieu, has made a discovery which will probably produce a revolution in the system of lighting and heating public and private buildings. He has invented a new pile much stronger and at the same time cheaper than the pile of Bunsen. By means of his photo-electric apparatus, he produces an electric light as cheap as gas; and with his thermo-electric pile, he supplies caloric on economical terms hitherto unknown. Several of these apparata have been constructed, and one is at full work in the Abbeye de la Grace-Dieu. Manufactories for the public are shortly to be established in Paris and at Lyons. The apparatus for producing gas will not be given to the public until after the exhibition at London next year; but that for heating buildings will be made public on the 16th of December next. The inventor has been authorized to make public experiments with his system of lighting on the Place Saint Jaques in Paris, and also on the Place Bellecourt at Lyons."

As to motive power, we learn that some of the most prominent electricians of France, England, Germany, and Russia, have for the last few years been most actively engaged in constructing machines, and it is said that the Emperor of France has given great attention and facilities to the scientists engaged in these important experiments.

Philadelphians: Your city, the home of the illustrious Franklin, has done much, perhaps more than any other city in the Union, to advance the sciences and arts. Shall we be outstripped by the efforts of our European neighbors?

I shall present to you this evening a communication of great importance on one of these subjects, the production of light and chemical decomposition, by a new magneto-electric apparatus, the invention of my worthy friend Dr. P. H. Vander Weyde, Professor of Chemistry and Physics at the Cooper Institute in New York. This gentleman has experimented for years past on magneto-electricity, and his communication is of interest and value. Perhaps at the next meeting of the Institute I shall be able to exhibit a large and powerful machine, producing a most brilliant electric light.

It is a remarkable—I may, perhaps, add providential—coincidence, that the aforementioned communication has been followed by another coming from a different source.

Mr. Herrman Haug, a Prussian engineer, lately arrived from Europe (a graduate of the Royal Polytechnic Institute at Berlin), sends a highly interesting communication on a *new Electric Motor.*

The advantages of a *cheap* electric motive power are too well known —the absence of fire alone, without taking into account the danger caused by the pressure of steam, or even of heated air—would give, even at a greater cost, to such a motor a high recommendation.

I reserve the reading of his communication for the next meeting, as it will require your full attention, involving some new and very peculiar modifications of natural laws. I can, however, show to you a drawing of a machine which has since been modified and perfected. It would be strange indeed should these two inventions secure to this country the honor, and why not the victory over our European rivals?

Mr. Fleury then read and explained by diagrams the following Description of New Magneto-Electric Machines, constructed on a principle differing from the usual method, by Dr. P. H. Vander Weyde, Instructor in Physics and Chemistry at the Cooper Institute, New York.

Last winter I read a paper before the Polytechnic Club of the American Institute, on the different methods of producing and using electricity to ignite inflammable substances. I exhibited the drawings and models of a few magneto-electric machines of my construction, adapted to ignite gas or gunpowder, by means of a magneto-electric current.

An extract from this paper and reports of the experiments performed are found in the Transactions of the American Institute for 1860, pp. 547-554, in a January number of the Scientific American, and in the American Engineer for January 10th, 1861.

I have since made numerous experiments to find the most advantageous arrangements to obtain the different purposes those machines may be intended for, have constructed small working models, and am now preparing two different very effective machines on a large scale.

Before speaking of my investigations since then, I will first in a few words describe the four new machines explained at that time, as this will serve to make the advantages offered by the two arrangements I have finally adopted better understood.

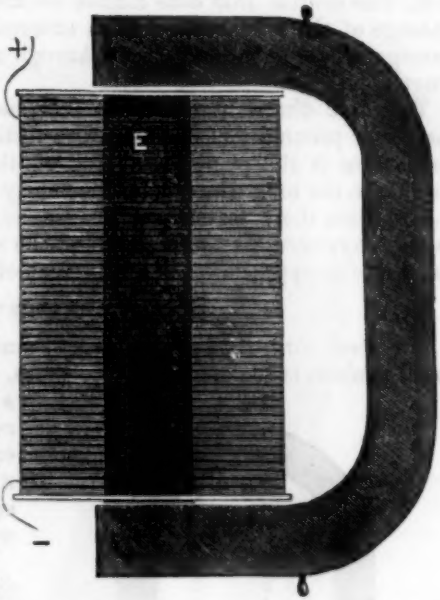
In each of my new arrangements, my purpose is (as the name "Magneto-Electric" indicates) to do away entirely with the cumberous and expensive galvanic batteries which are the main objections to the use of the Ruhmkorff-coil and other arrangements made after the same principle, and to substitute for the battery, the action produced by permanent steel magnets, moved by some mechanical power.

The question was only to arrange a given quantity of steel so as to obtain the strongest permanent magnetism, and to arrange a given quantity of insulated copper wire so as to obtain by that magnetism put in motion, the greatest amount of electricity.

First Arrangement.

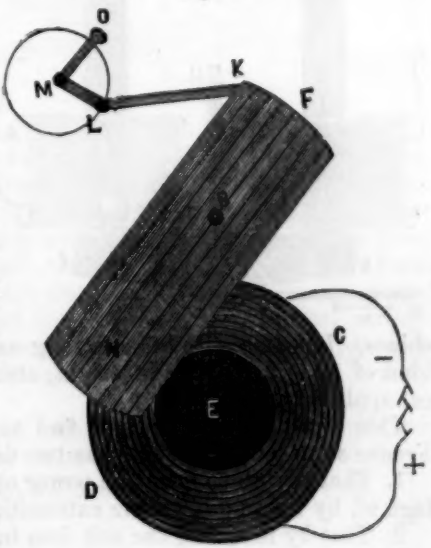
Of the first arrangement I contrived, the principle is represented in figs. 1 and 2, the first being the front and the second the side view of the apparatus.

Fig. 1.



It is an imitation of the Ruhmkorff-coil, except that in place of magnetizing the central iron core, E, by the current from a galvanic battery, (passing through a coil of thick wire, around which the long thin wire is wound,) in this arrangement the central iron core is magnetized by a bundle of horse-shoe magnets, oscillating around a pivot, B, and passing with their poles close along the extremities of the iron core. By this arrangement the central thick wire is entirely dispensed with; the thin wire of several thousand feet in length is wound directly on the insulating glass or india rubber surrounding the core, and also wound in sections, as is the case in the improved apparatus of Ruhmkorff; by which means, united with the perfect insulation of the windings from the core by glass, india rubber, &c., a long spark is produced.

Fig. 2.



I do not wish to have the value of this arrangement overestimated, and therefore will also mention its disadvantages.

1. The thick primary wire being omitted, the condenser, which increases the spark of Ruhmkorff's apparatus, and which is connected with this wire and the battery, cannot be here applied.

2. The magnetism cannot be so suddenly excited or neutralized in the central core, by the passing of the steel magnets along its extremities, as is the

case in the Ruhmkorff-coil, by making and breaking the contact of the battery; the suddenness of this operation constituting one of the sources of its efficiency.

3. The central iron core cannot be magnetized so strongly by the passage of the magnets along its extremities, as in the core by the passage of the galvanic current through a wire surrounding its whole length.

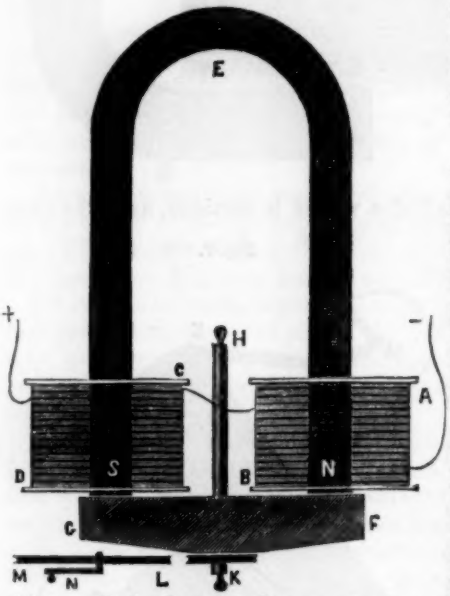
This last disadvantage is, however, more or less compensated by the closer proximity of our long wire to the central core, of which the magnetism is the principal source of the intensity current, giving sparks, in the long wire; as is sufficiently known.

I mention these particulars because, as I remarked above, they are useful, nay, necessary to understand the subject in question, and will also serve to appreciate the advantages of my other arrangements.

Second Arrangement.

The steel horse-shoe magnet, S E N, consisting of three or five superposed laminæ, is rounded off at the poles, around which the two coils, A B and C D, are wound; F G represents the soft iron keeper, revolving around the axis, H K, by means of the crank, N, and the intervening wheel-work, M L.

Fig. 3.



A small working model of this machine, intended to prove the correctness of the principle that the coil may be advantageously wound round the steel magnets, is now in the hands of my friend, Prof. Fleury, in Philadelphia. Its dimensions are so small that it may be carried in the pocket without the least inconvenience; for this reason I have it specially arranged for medical purposes, and attached to it the usual contact breaker and commutator of the good medical magneto-electric machines. It is found to be as strong as many large machines of this kind of 10 to 20 pounds in weight, and amply sufficient for all medical applications.

This arrangement (which I find to have been already made in France some four years ago) has two defects.

1. That the whole magnetic power of the steel is not taken advantage of, by winding alone the extremities.

2. That by revolving the soft iron in front of the magnet we have

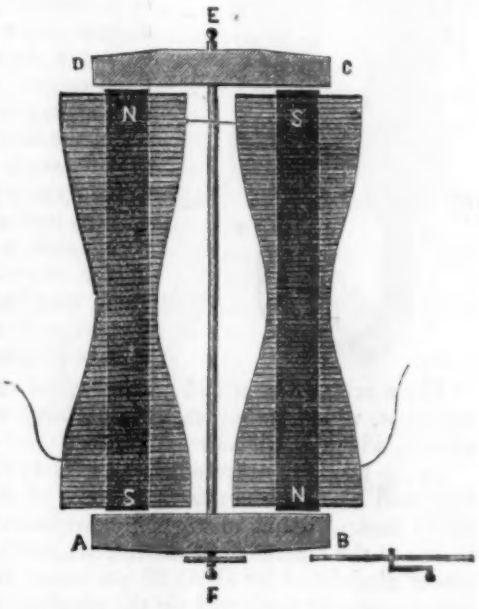
no perfect contact, and do not make all the magnetism latent, thus exciting the current only with the difference of the full and a greatly diminished power.

I have succeeded in obviating these difficulties by two separate arrangements, which are the subject of my patent.

Third Arrangement.

I have taken two steel bars, each composed of a bundle of five or seven laminæ, strongly united and rounded off; each is surrounded by a hollow cylinder of glass, india rubber, or any other good insulating substance, of the same length as the bars, and open at both ends; around these the coil is wound for the whole of their extent, observing two things: first, to wind it in sections, as the Ruhmkorff-coil, to insure more length of the spark; secondly, to so distribute it over the length of the magnetic bars, that most of the coil will be where the greatest magnetic intensity resides, that is, towards the extremities.

Fig. 4.



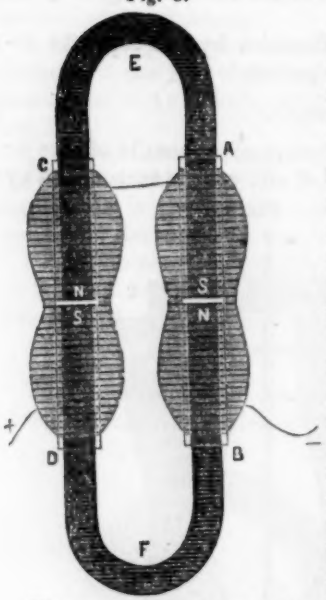
The two bars and coils are then horizontally attached to a board or placed in a box, equally distant from and parallel to an axis, which is a little longer than the steel bars.

In fig. 4, N S represent the steel bars and coils, E F the axis; at each extremity of this axis is attached a keeper, A B and C D, at right angles, and at such a distance that by turning the axis the keepers pass with their ends very closely along the extremities of the steel magnets, which of course lay with the opposite poles toward the same keepers. It is clear that in this arrangement we have the advantage of the whole magnetic surface of the steel magnets, being made available by the coil, and at the same time working with an apparatus more than double the power of that represented in fig. 3, and exactly of the same dimensions.

The remaining disadvantage of imperfect contact of the keepers and magnet, is entirely overcome in the following:

Fourth Arrangement.

Fig. 5.



I take two strong horse-shoe magnets, having polished cylindrical extremities, E and F, and place them horizontally on a board or in a box, touching each other with their opposite poles, N S, which are situated in two coils, A B and C D. These coils, wound of well insulated copper wire, are immovable, and fixed to said board. One of the magnets must slide in and out of the coil, and may be suddenly separated from the opposite fixed magnet which attracts it, by means of a strong lever. The moment this is done, the magnetism of the two magnets (before made latent by their contact) is suddenly set free, and induces an electric current in the coils; by joining the magnets again, a current will be developed in the opposite direction, which, if desired, may be led in the same direction by means of an appropriate commutator attached to the lever.

The machines described under Figs. 4 and 5 have both peculiar advantages, which adapt them to perform electric labor of a different nature, which I will now explain.

In the machine represented by Fig. 4, the contact cannot be absolute, and therefore is the magnetism of the steel magnets not so entirely neutralized as in Fig. 5; therefore the electric power of Fig. 4 is due to the difference in the full magnetic power of the steel, and its power diminished by about 98 per cent. In Fig. 5, the magnetism is almost entirely destroyed by the absolute contact, so that scarcely a trace is left; however, to compensate for this slight defect in machine Fig. 4, these machines are apt to run with great velocity while Fig. 5 is not.

Fig. 4 is therefore appropriate to the following purposes:—

I. *For Electro-plating*, if a series of medium-sized machines are constructed, connected by thin coils, and moved together.

II. *For Chemical Decomposition.* If these series are so constructed that the connexion of their coils may be arranged differently, either for intensity or for quantity; as the coils and magnets are all stationary, it is exceedingly easy to change these connexions, even while the machine is running, till the intended result, chemical decomposition, is obtained. However, as I find the law of Ohm (that the resistance in the conducting wire or coil must be equal to the resistance in the liquid of the battery) applicable to these machines, in which the resistance of the coil must be equal to the resistance in the chemical solution to be decomposed, we may, by calculating the resistance which

this liquid offers to the electric current, connect the coils in such a way as to make the resistance in them equal to that in the liquid, and thus arrange the connexions *à priori*.

III. *For Medical Purposes*, if the machines are constructed on a small scale, and provided with a commutator, as in the machine (No. 3 above) now in the hands of Prof. Fleury.

IV. *For Electric Light*, if the precautions in the construction are adopted which I have found by many successful experiments to be necessary to secure a long spark, and which thus far have never been obtained in machines of this kind. Of these precautions and peculiar arrangements, I will speak hereafter. They are of absolute necessity for the apparatus represented in Fig. 5, which is the great desideratum so long sought for and wanted for military purposes.

V. *For Igniting Gas, Gunpowder, and other inflammable substances.* For this purpose, the machine Fig. 5, is to be constructed with special regard to obtaining a single but very powerful spark.

To obtain such a spark, the precautions are:—

1. To have the magnets carefully rounded off at the poles, well fitting, and exactly filling the opening in the coils.

2. To have the ends well ground on a plane, to secure a perfect contact.

3. To insulate the coil carefully in winding it over the glass or india rubber, to prevent the spark from losing its intensity and length by discharging partially through the magnets, as is the case in all other machines; also, to avoid the mistake of having metallic or other conductive rings connected with those coils, which absorb a part of the electric effect of the magnets at the expense of the coils.

The necessary peculiarities of the arrangement are:—

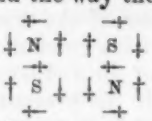
1. To construct each magnet of a bundle of smaller magnets, each of such size and shape as have been found by Lamont the most effective (see Poggendorf's *Annalen*, July, 1861).

2. To insulate the extremities of all these small magnets from one another, so as to prevent the circulation of any electric current in the bundle of magnets (to the production of which there is a tendency), and thus to force all the magnetism producing the electric current to be exerted in the coil.

3. To wind the coil in a peculiar way (described in Poggendorf's *Annalen*, a few years ago), to insure longer sparks. A single apparatus of this kind suffices for igniting gas or gunpowder by means of some easily explosive compound, as I have proved by experiment, even with the old apparatus (see Transac. Am. Inst., 1860, p. 549). Where, however, more intensity is required to make it work at greater distances, a battery of such coils as Fig. 5 is to be arranged by placing the magnets vertically: the upper ones fixed, and the lower ones movable, so that, by the downward motion of a powerful lever, they may be at once separated from the upper, each pair surrounded by its coil.

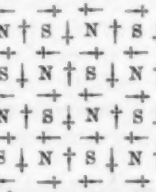
The way these poles have to be arranged, is for the lower magnets (that is, those having their poles turned upward, if we look from above

down on them) here represented; N signifies the north pole, and S the south pole, of each horse-shoe; the arrows indicate the direction of the current in the coils, and the way these coils must be connected.



It will be seen how, by this arrangement, every pole assists the currents in the coils of the neighboring opposite poles; those four poles are neutralized by the contact of the opposite poles of the upper inverted magnets, but this inverted position brings the current in the same direction.

For 16 poles, the arrangement would be thus; the arrows again indicating the direction of the current:—



Such a combination will require the full power of one or two men to separate the sixteen poles by means of the lever, but by my careful and peculiar arrangement, will give an electric spark equivalent to the power applied, and will act at any distance which practically may be wanted, only requiring the common precaution for insulating the conducting wires.

The patents applied for, cover all the essential parts of the machines represented in Figs. 4 and 5, as well in their single construction as in their combination to a powerful battery, and the use of this battery for the purposes mentioned, as also for such effects as can be produced by any ordinary electric machine or galvanic battery.

Cooper Institute, New York, Nov. 10th, 1861.

Mr. Howson presented a Calisthenic or Gymnastic Apparatus, invented by Mr. R. A. Maxwell, of Eleventh and Chestnut Streets, which attracted much attention. This instrument occupies a space of about two cubic feet, and can be regulated to give a resistance of from 6 to 600 lbs. All exercises for which cumbrous devices and gymnasia are provided, can be practised by the aid of this instrument.

METEOROLOGY.

For the Journal of the Franklin Institute.

The Meteorology of Philadelphia. By James A. Kirkpatrick, A.M.

October.—The month of October was warmer than usual. The mean temperature was greater than that of any October for the last eleven years, and was one-third of a degree greater than in October, 1858, which had heretofore been the highest.

The warmest day of the month was the 6th, of which the mean temperature was 78·3°. The highest degree of heat indicated by the register thermometer was 88°, on the same day.

The coldest day was the 28th, with a mean temperature of 43½°. The register thermometer indicated the lowest degree (34°) on the same day.

The range of temperature for the month was 54°.

The greatest change of temperature in the course of a day was 25°, on the 15th; the least was 8½°, on the 10th; and the average oscillation for the month (16·94°) was more than one degree greater than the general average, but less than one degree more than that of October, 1860.

The greatest mean daily range of temperature was 13°, and occurred between the 7th and 8th days of the month; the least was 1·3°, and occurred between the 9th and 10th. The average daily range for the month was 5·28°, which was about a quarter of a degree less than usual. It was less than in any October since 1857, when the average daily range was 4·3°.

The greatest pressure of the atmosphere was 30·452 inches, and was observed at 7 A. M. on the morning of the 25th. This is the highest point indicated by the barometer, in the month of October, during the eleven years of observation. The highest heretofore (30·410 ins.) occurred at 9 A. M. on the 27th of the month, in the year 1852. The minimum pressure was 29·469 inches, and occurred at 2 P. M. of the 30th. The monthly range of pressure was 0·983 of an inch. The average pressure for the month was fifteen-thousandths of an inch less than for October, 1860, but five-thousandths of an inch greater than the average for eleven years.

The greatest mean daily range of pressure was 0·423 of an inch, between the 23d and 24th; the least was 0·03 of an inch, between the 18th and 19th; and the average for the whole month was 0·166 of an inch, which is greater than any average daily range of pressure for this month since 1853, when it reached 0·170, and it is nearly two-hundredths of an inch greater than the average for the eleven years of observation.

The average relative humidity was greatest on the 19th and least on the 28th of the month. The average for the whole month, as computed from that of the regular hours of observation, was 72½ per cent. of complete saturation, which is almost the same as that of October, 1860, but 3 per cent. greater than the average for the last eleven years.

The force of vapor was also greater than usual. At every hour of observation it was greater than before observed in this month for the last eleven years. The average for the whole month was 0·399, while the general average for the whole time of observation was 0·331 of an inch. The force of vapor was greatest (0·731 in.) on the 7th, and least (0·122 in.) on the 28th of the month.

The dew-point, following the force of vapor, was also greater than for any other October for the last eleven years. The highest was 69·9°

on the 7th; and the lowest, 22·7° on the 28th. The mean dew-point for the month at 7 A. M. was 48·65°, at 2 P. M. 51·43°, and at 9 P. M. 51·07°, making the average for the month 50·38°. The average height of the dew-point at 2 P. M. for this month for the last eleven years was 46·67°.

Rain fell on ten days of the month, to the aggregate depth of 3·597 inches, which was one inch less than that which fell in October, 1860, but three-quarters of an inch more than the average for the whole time of observation.

There were but two days of the month, the 14th and 28th, entirely clear, or free from clouds at the hours of observation, and the sky was completely covered with clouds at those hours on nine days of the month. The average amount of cloudiness was nearly one-tenth of the sky more than usual. The average amount of sky covered for October for the last eleven years was five-tenths, while for the last month it was almost six-tenths.

On the morning of the 28th of the month, ice was formed in exposed places in the western part of the city, the sixteenth of an inch in thickness. It has not yet been observed in the built-up parts of the city. The first ice was observed last year on the 21st of November.

A Comparison of some of the Meteorological Phenomena of OCTOBER, 1861, *with those of* OCTOBER, 1860, *and of the same month for* ELEVEN *years, at Philadelphia, Pa.* Latitude 39° 57½′ N.; longitude 75° 10½′ W. from Greenwich.

	Oct. 1861.	Oct. 1860.	Oct. 11 years.
Thermometer.—Highest,	88°	79°	90°
" Lowest,	34	36	28
" Daily oscillation,	16·94	16·10	15·77
" Mean daily range,	5·28	5·80	5·55
" Means at 7 A. M.,	54·32	51·58	51·28
" " 2 P. M.,	66·61	63·29	63·36
" " 9 P. M.,	58·69	55·61	55·50
" " for the month,	59·87	56·83	56·71
Barometer.—Highest,	30·452 in.	30·275 in.	30·452 in.
" Lowest,	29·469	29·312	29·012
" Mean daily range,	·166	·119	·145
" Means at 7 A. M.,	29·945	29·963	29·937
" " 2 P. M.,	29·893	29·906	29·895
" " 9 P. M.,	29·926	29·938	29·916
" " for the month,	29·921	29·936	29·916
Force of Vapor.—Means at 7 A. M.,	·373 in.	·321 in.	·318 in.
" " " 2 P. M.,	·415	·363	·350
" " " 9 P. M.,	·410	·354	·324
Relative Humidity.—Means at 7 A. M.,	81 per ct.	80 per ct.	79 per ct.
" " " 2 P. M.,	60	61	57
" " " 9 P. M.,	76	77	74
Rain, amount in inches,	3·597 in.	4·695 in.	2·855 in.
No. of days on which rain fell,	10	13	8·8
Prevailing winds—Times in 1000-ths,	s75°10′w ·211	s75°58′w ·069	s73°40′ w ·251

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